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G. A. COOK, M.Sc., B.M.E.

Assistant Editor:
MARTIE E. HAMILTON, B.Sc.

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Inert Mineral Dusts as a Means of Control for Potato Moth, *Phthorimaea operculella* Zell., in Stored Potatoes.

*By G. A. H. Helson, M.Sc.**

Summary.

Of the mineral dusts tried as substitutes for derris, finely ground magnesite used at the rate of 20 lb. to the ton, was most satisfactory in laboratory tests. It reduced the number of eggs deposited by females, acted as a larvicide, and is sufficiently effective and cheap to be used as a substitute for derris. Its efficiency does not appear to be affected by humidities below 80 per cent. The dust, however, will not prevent injection of the sprouts which form after treatment.

1. Introduction.

The potato moth, *Phthorimaea operculella* Zell., which is a serious pest of potato crops in nearly all potato growing districts on the mainland of Australia, was particularly bad in the eastern States during 1941-42. At Canberra, heavy infestations occurred in plots used for virus transmission studies and in plots of virus-free stocks being multiplied for seed. Tubers of this latter stock were threatened with further attack in storage, and, as it was considered that fumigation might interfere with later dormancy-breaking treatment, some other form of treatment to protect this valuable seed was necessary.

It had been shown that dusting the tubers with derris (1) would control the pest in stored tubers, but, when supplies of this insecticide became unprocurable, it was necessary to find, if possible, a cheap and readily available substitute.

Recently a new method of controlling weevils in grain by means of finely-ground, chemically inert, mineral dusts has been developed. It is now generally accepted that these dusts owe their efficiency primarily to dehydrating action. Ratcliffe, Gay, and Fitzgerald (2, 3) found that magnesite and limonite were the best of the Australian mineral dusts tested, and that magnesite (magnesium carbonate) ground to pass through a 200 mesh-to-the-inch sieve gave complete control of the granary weevil. It was thought that some of these inert dusts might prove effective for the control of potato moth in stored tubers.

* An officer of the Division of Economic Entomology.

The following experiments were performed in the laboratory using magnesite, lime, and dolomite ground to pass a 200 mesh sieve. Of these, magnesite was the most satisfactory, but there has been no opportunity to test the efficiency of this dust on a commercial scale. As it has shown so much promise in the laboratory tests, however, and as the need for a derris substitute is urgent, it was decided to publish these results pending large-scale trials.

2. Method.

All experiments were carried out at a constant temperature of 26·7°C., and 10-in. by 8-in. glass jars covered with cellophane were used for oviposition cages. Sometimes moths were permitted to deposit eggs directly on the potatoes, but usually a small piece of organdie was supplied on which they oviposited freely. In the experiment carried out at different humidities, a stream of air from a small Marco pump was split into four streams which passed through gas wash bottles half filled with glass beads and containing sulphuric acid of required specific gravity. After conditioning in the wash bottles, each stream of air passed through a small scrubber filled with soda-lime to remove any acid and then passed through two 2-lb. glass jars containing the potato tubers under test.

Potatoes were dusted at the rate of 20 lb. to the ton by putting tubers and excess dust into a round aridor jar which was rotated and moved up and down on its long axis at the same time. Any excess dust was blown off the tubers after removal from the jar. Larger quantities of seed potatoes were treated by rotating in a drum such as that used for pickling seed. A suitable type for use on the farm is illustrated in *Agric. Gaz. N.S.W.* (4). In practice it was found best to place the tubers in the drum first and to distribute the required amount of dust on top of the potatoes along the whole length of the drum. After dusting the potatoes should be stored in a cool, dry, well-ventilated place, and if bagged should be placed in bags the insides of which have been dusted with magnesite.

3. Experiments.

(i) *Effect on Oviposition.*

Seventeen moths were placed in an oviposition jar together with four potatoes, three of which were dusted with magnesite, derris, and dolomite respectively, and the fourth was left undusted. At the end of four days three eggs were laid on the tuber treated with magnesite, four on the one treated with derris, five on the one treated with dolomite, and 27 eggs on the untreated potato. Eggs were laid on both the skin and eyes of the tuber in all cases except the tuber treated with derris, where oviposition occurred on the skin only.

(ii) *Effect on Larvae.*

A medium sized tuber dusted with magnesite was placed in a petri dish with an untreated tuber of approximately the same size and 31 eggs about to hatch were planted in and around the two potatoes. Three days after hatching the dusted potato showed one shallow penetration only, whereas the untreated tuber showed five deep penetrations.

Three medium sized potatoes dusted with magnesite, together with three untreated tubers, were then placed in an oviposition jar and approximately 100 larvae in all stages of development were planted among the tubers. Two days later there were two very shallow penetrations into the dusted tubers, compared with 44 into the untreated potatoes.

Next, groups of three tubers dusted with magnesite, derris, and dolomite respectively, and a fourth untreated were placed at random on the bottom of an oviposition jar and 200 larvae in all stages of development were planted among the tubers. Four days later many of the larvae had died after contact with the derris, and a few had pupated. Of the remainder, six entered the untreated tubers and six the potatoes dusted with dolomite; the tubers treated with magnesite and derris remained untouched.

After these small tests a larger experiment was planned in which 360 potatoes of approximately equal size were divided into six groups of 60 tubers. Four groups were dusted with magnesite, derris, dolomite, and lime respectively, a fifth was treated for a few seconds by immersion in a proprietary emulsion of eucalyptus oils diluted with water at rate of 1 part of oil to 30 parts of water, and the remaining group was left untreated. After treatment each group of tubers was further subdivided into six lots of ten potatoes, which were sealed in calico bags together with a thoroughly infested potato. The bags were stored at a constant temperature of 26·7°C. for 36 days before being opened and examined (Fig. 1). The results are shown in Table 1.

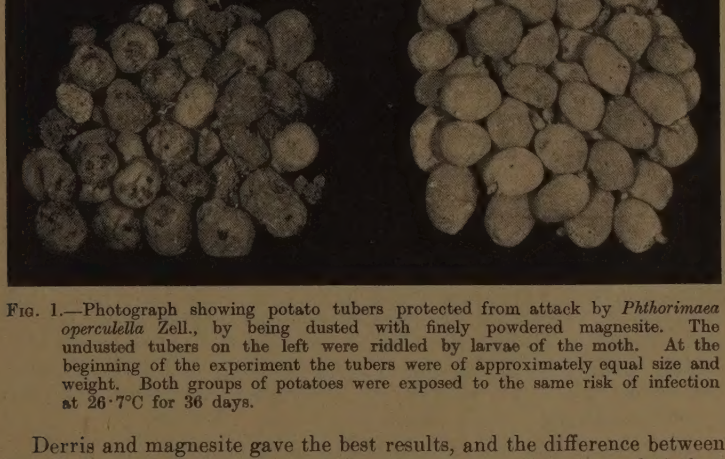

Fig. 1.—Photograph showing potato tubers protected from attack by *Phthorimaea operculella* Zell., by being dusted with finely powdered magnesite. The undusted tubers on the left were riddled by larvae of the moth. At the beginning of the experiment the tubers were of approximately equal size and weight. Both groups of potatoes were exposed to the same risk of infection at 26·7°C for 36 days.

Derris and magnesite gave the best results, and the difference between the effectiveness of these two and the other treatments is so marked that, without statistical analysis, it is seen to be highly significant. Derris was more effective than magnesite, which does not give complete protection, and will not protect sprouts which develop subsequent to treatment.

TABLE 1.—THE COMPARATIVE VALUE OF DIFFERENT TREATMENTS AGAINST THE LARVAE OF *P. operculella*.

Treatment.	Number of Tubers Affected.	Number of Tubers Unaffected.	Percentage of Tubers Affected.
Derris	1	59	1·70
Magnesite	3	57	5· 0
Dolomite	48	12	80· 0
Lime	49	11	82· 0
Eucalyptus emulsion ..	52	8	86· 6
Untreated	60	..	100· 0

In order to determine the maximum amount of the various dusts which a given weight of tubers would retain, each bag of potatoes in the above experiment was weighed before and after treatment. The total weights for each treatment are shown in Table 2.

TABLE 2.—THE MAXIMUM AMOUNT OF VARIOUS DUSTS RETAINED BY DIFFERENT WEIGHTS OF POTATOES.

Treatment.	Weight before Dusting.	Weight after Dusting.	Weight of Dust Retained.	Weight of Dust Retained by 100 g. Potatoes.
	g.	g.	g.	g.
Derris	2930·0	2955·0	25·0	0·85
Magnesite ..	2777·0	2801·5	24·5	0·88
Dolomite	2810·0	2827·5	17·5	0·62
Lime	2645·0	2656·0	11·0	0·42

The maximum amount of derris and magnesite retained is almost the same and the amount of dolomite and lime much less. The amount of magnesite retained by the tubers is the equivalent of 20 lb. to the ton, but in practice this amount of dust will vary slightly depending on the size of the tubers.

Another experiment was made to determine the degree of infestation which would develop in the various treatments when moths were given no choice for oviposition other than tubers treated with various dusts. Twenty-five potatoes were divided into groups of five, four of which were treated with magnesite, derris, dolomite, and lime respectively, and the remaining group left untreated. Each group of tubers together with ten mature moths was placed in an oviposition jar covered with muslin. The experiment was repeated using an oviposition jar covered with cellophane on which the moths do not oviposit. After twenty days the tubers were cut and the number of live larvae in each tuber recorded. The results are shown in Table 3. Derris and magnesite gave best protection again.

In all these tests the number of larval penetrations into individual tubers dusted with magnesite was markedly less than into untreated potatoes, which were usually almost completely riddled. Dusted potatoes suffered less from rots and breakdown which accompany the tunnelling of larvae.

TABLE 3.—EFFECT OF VARIOUS DUSTS ON INFESTATION OF TUBERS.

Treatment.	Number of Larvae Alive in 1st Experiment.	Number of Larvae Alive in 2nd Experiment.
Derris	0	0
Magnesite	8	5
Dolomite	36	7
Lime	43	13
Untreated	94	47

(iii) *Effect of Humidity on the Efficiency of Magnesite.*

Records of the moisture conditions inside a sack of potatoes stored in the laboratory at Canberra showed that over a period of three weeks the humidity rose until it reached an equilibrium varying between 60 and 70 per cent., and that the daily variations in the surrounding atmosphere outside the bag did not have any appreciable effect. As the humidity of the surrounding atmosphere rose towards midwinter, however, there was an upward drift inside the sack until a relative humidity of 70 per cent. was reached.

After this, two small scale laboratory tests at relative humidities of 50, 60, 70, and 80 per cent., and a larger test using 400 potatoes at humidity 50 and 80 per cent. respectively, at a constant temperature of 26·7°C., showed that humidities up to 80 per cent. did not reduce the efficiency of the magnesite. At humidities approaching saturation, however, the protective qualities of the dust appear to break down.

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Breaking Dormancy of the Potato.

*E. M. Hutton, B.Agr. Sc., M.Sc.**

Summary.

1. Dormancy in the potato can be successfully and cheaply broken by placing whole or cut tubers for 4–5 hours in acetylene solutions made by adding small pieces of calcium carbide to water, the addition being gradual over a quarter of an hour.

2. Acetylene compares very favorably with the relatively expensive thiourea which gives better results only with varieties such as Snowflake which are extremely dormant. Even with varieties such as Snowflake, acetylene is quite successful from a practical point of view.

3. Whole or cut tubers can be used. Except with very dormant material, cutting the tubers immediately before treatment is not an advantage.

4. If the acetylene treated material is not planted immediately, it should be kept in a warm moist place for 1–2 weeks to initiate sprouting when it can be dried off to green and form sturdy sprouts.

5. Acidulated corrosive sublimate treatment for *Rhizoctonia* scab is best given after the initiation of sprouting, as this dip tends to depress sprouting if it follows immediately dormancy-breaking treatments.

1. Introduction.

In the course of a series of potato investigations it became desirable to reduce the dormancy period of potato stocks in order to speed up the work. It is well known that compounds such as thiourea, ethylene chlorhydrin, and sodium thiocyanate are effective in breaking dormancy of potato tubers.

The general experience indicates that the speed with which dormancy is broken depends not only on the chemical used but on the variety of the potato. Stuart and Milstead (7) demonstrated that Katahdin, Prolific, and other varieties are sensitive to dormancy-breaking treatments and have a short rest period, whereas such varieties as White Ohio and Queen of the Valley have a long rest period, and it is more difficult to break their dormancy. Experience at Canberra with dormancy-breaking treatments indicates that Factor, Delaware, Katahdin, Sebago, Carman, and Bismarck are not very dormant, whereas Brownell is more dormant, and Snowflake is the most dormant Australian variety yet handled. Using ethylene chlorhydrin with the least dormant varieties, e.g., Katahdin, Stuart and Milstead (7) found that sprouting in a proportion of the sample was not obvious for a week, and sprouting of all the tubers did not occur before 3 weeks after treatment. Michener (5) using the same treatment obtained sprouts 1–3 mm. long on Bliss Triumph tubers 23 days after treatment. This is in accord with the results at Canberra using the same chemicals.

2. Preliminary Experiments at Canberra, 1941.

Freshly dug dormant Katahdin potatoes were treated with ethylene chlorhydrin and thiourea. After treatment the material was planted in moist sawdust and the results shown in Table 1 were calculated 3 weeks after, when the sprouts averaged 5 mm. long and the controls showed insignificant sprouting.

* Assistant Geneticist, Division of Plant Industry.

TABLE 1.—RESULTS WITH KATAHDIN.

Chemical.	Treatment.	Average Sprouts per tuber.		Average Sprouts per eye.	
		Potatoes Cut.	Potatoes Whole.	Potatoes Cut.	Potatoes Whole.
Ethylene chlorhydrin	Vapour—5 ml. per 3,000 ml. for 24 hours	5·25	3·0	2·0	1·7
Ethylene chlorhydrin	Dip—10 ml. per 1,000 ml. water for 1 hour	12·3	2·3	2·6	1·6
Thiourea	4 per cent. solution for 1 hour	5·3	1·2	1·7	1·0

The object of these small-scale experiments was to find a cheap and effective method which could be used for breaking the dormancy of virus-free potatoes which had been isolated by Bald and Norris (1) and which were to be multiplied quickly by growing two crops a year. It was apparent that these chemicals were quite effective on one of the varieties which were to be multiplied, but it was obvious that the cost would be prohibitive on a large scale, especially when the most effective chemical, ethylene chlorhydrin, was a chemical rarity in Australia. Even in America the cost is a limiting factor to the general adoption of dormancy-breaking methods.

3. Preliminary Experiments with Acetylene as a Dormancy-Breaking Chemical.

Zimmerman and Hitchcock (8) used acetylene successfully to stimulate adventitious roots, Lewcock (4) used it to induce early flowering in pineapple plants, and Copisarow (2) describes it as a general growth promoter and fertilizer. Using acetylene as a gas to break the dormancy of potato tubers, Denny (3) reported that in no case with both whole and cut tubers were favorable forcing effects noted, even when the material was held for 7 days in a 1:100 of air concentration of the gas. As a result no further attempts appear to have been made to break the dormancy of potatoes with acetylene, in spite of its proved hormone-like effect for other purposes in plants. Lewcock used acetylene in solution to induce flowering of pineapples, and as acetylene solution had not been tried for breaking the dormancy of potatoes, as far as could be ascertained from the literature, it was decided to investigate its possibilities for this purpose.

In the first experiments at Canberra acetylene was generated from commercial calcium carbide and bubbled through water for 15 minutes to make the acetylene solution. Freshly dug Katahdin tubers were cut and placed in the acetylene solution for periods up to 24 hours. These experiments were a complete failure due to soft rot of all the sets. Similar experiments with whole uncut Katahdin tubers from the same digging were a complete success, as after three weeks the treated tubers had shoots 6–10 cm. long, whereas the controls had just shown signs of beginning to sprout. The time of immersion, which varied from ½ to 24 hours in the acetylene solutions, appeared to have little effect on degree of sprouting.

4. The Effect of Acetylene Solutions on Breaking the Dormancy of Snowflake.

Snowflake is the most dormant Australian potato variety so it was chosen to test definitely the usefulness of the acetylene method to potato growers. Freshly dug Snowflake was treated with acetylene solution, 2 per cent. thiourea, and water, each for 4 hours, the results in Table 2 being obtained one month after treatment. The acetylene solution was made by adding small pieces of carbide to water in a container during a quarter of an hour so that the gas was bubbling continually through the water. In this way saturation of the solution with acetylene was approached. After the treatments cited in Table 2, the material was placed on moist sand in the glasshouse. Ten medium to large tubers were used for each treatment.

TABLE 2.—RESULTS WITH SNOWFLAKE, USING 2 PER CENT. THIOUREA, ACETYLENE SOLUTION, AND WATER FOR 4 HOURS.

A. Per cent. sprouted sets.
B. Mean number sprouted eyes per sprouted set.
C. Mean number sprouts per sprouted eye.

Treatment of Tubers Before and After Immersion in the Solutions.	2 per cent. Thiourea.			Acetylene.			Water.		
	A.	B.	C.	A.	B.	C.	A.	B.	C.
1. Tubers halved and suberized 48 hours before treatment	100	5·0	1·7*	100	2·0	1·0†	10	1·0	1·0
2. Tubers halved and treated immediately	100	4·0	1·3*	100	2·4	1·5†	10	1·0	1·0
3. Tubers treated whole and cut immediately	80	1·3	1·3	40	1·8	1·3	nil	..	..
4. Tubers treated whole ..	100	1·0	1·0	86	1·0	1·0	30	1·3	1·6

* Sprouts averaged 2–3 cm. long.
† Sprouts averaged 1–2 cm. long.

Table 2 demonstrates that to obtain the quickest results, cutting the tubers just before the dormancy-breaking treatment is necessary. In this experiment, the best acetylene treatment is the one in which the tubers are immersed in the solution immediately after cutting, and the best thiourea treatment is the one in which the cut sets are suberized 48 hours beforehand. Comparing the thiourea treatments with the acetylene and using very dormant material, it is apparent that acetylene solutions, although not quite as efficient as thiourea, have distinct promise as they caused 100 per cent. of the cut sets and 86 per cent. of the whole tubers to sprout after a month. The fact that acetylene caused 86 per cent. of the whole tubers to sprout compared with 100 per cent. for thiourea does not detract from the value of acetylene solutions commercially for breaking dormancy, since the "eyes" of the unsprouted tubers evinced distinct signs of early sprouting. The low cost and ease of application of acetylene solutions compared with other dormancy-breaking substances and the fact that the most dormant commercial variety, Snowflake, grown in Australia could be successfully treated with acetylene either as cut or whole sets made it apparent that it was the best method for treating the virus-free material mentioned

previously. Further small-scale tests with both whole and cut tubers of Factor, Carman, Bismarck, and Katahdin confirmed this view and demonstrated that where dormancy is not pronounced, as in these varieties, there is little difference between the dormancy-breaking effects of acetylene and thiourea.

5. Experiments with Carman and Factor.

To test the acetylene method on a semi-commercial scale, a sack each of dormant Carman and Factor potatoes recently dug were obtained, the former from Victoria, and the latter from New South Wales. These were given various treatments with acetylene from a cylinder in order to ascertain the optimum conditions of treatment.

In Table 3 are given the results of an experiment with these varieties. Separate enamel cans containing 5 litres of tap water were used in each treatment. For each treatment 32 tubers weighing approximately 1,560 g. in Carman and 1,380 g. in Factor were used, and the tubers were treated whole. Samples of the solution for acetylene analysis were taken immediately before potatoes were taken out of it. Acetylene was determined by the method of Schutz and Klauditz (6) and duplication of results was easily obtained. After treatment, the tubers were covered with sand in flats and kept moist in the glasshouse. The sprouting results in Table 3 were obtained after 21 days in Factor (see Fig. 1) and 42 days in Carman.

Table 3.—Results with Carman and Factor.

Time of Immersion in Hours.	Acetylene Bubbled Through 15 Minutes.		Acetylene Bubbled Through 30 Minutes.		Water Control.		Percentage Acetylene in Solution.	
	Mean Length of Sprouts in cm.							
	Factor.	Carman.	Factor.	Carman.	Factor.	Carman.	Bubbled 15 mins.	Bubbled 15 mins.
Before immersion	..	..	..	..	..	..	·0112	·0504
½	30·8	9·7	18·5	16·5	9·4	8·8	·0098	·0471
2	18·4	12·4	26·5	15·9	9·6	3·4	·0098	·0437
6	20·9	17·4	24·4	16·8	6·2	6·8	·0086	·0364
24	28·0	19·6	21·1	20·1	8·2	4·1	·0060	·0164

Standard Error { Factor ± 3·5 cm. / Carman ± 2·4 cm.

Comparing the results in Table 3, an immersion time of 4–6 hours in acetylene solutions appeared to be a practical optimum for general use. Helson* has found that acetylene solutions kill potato moth larvae present in the tubers, and that at least a 4-hour immersion is necessary for an almost complete kill, so that the adoption of a 4–6 hour immersion period would be desirable from this viewpoint. The least dormant Factor material was the more sensitive to time of immersion and concentration of acetylene in solution. It is apparent that quite low concentrations of acetylene in solution are effective and that high concentrations are not more effective proportionately, so that 15 minutes

* This *Journal*, p. 268.

bubbling is sufficient. With the lower concentrations, the loss of acetylene from the solution over 24 hours is not as great as with the more concentrated solutions.

6. The Application of the Acetylene Method Commercially.

As a result of the experimental work done with the acetylene method, a practical procedure for the commercial grower is to half fill a container with water and add gradually over a quarter of an hour small pieces of calcium carbide and then to place the potatoes to be sprouted in the solution so prepared for 4–5 hours. The treated material can then be planted immediately. When planting conditions are unsuitable or where it is desired to sprout and green the tubers a month or so before planting, best results are obtained by keeping the potatoes after treatment between moist bags for 1–2 weeks in a warm place to initiate sprouting, when they can be dried off and greened and planted when convenient.

FIG. 1.—Results with Factor after 3 weeks. 1C, 2C, and 4C are controls which were soaked in water ½ hr., 2 hrs., and 24 hrs. respectively. 1B, 2B 3B, and 4B were soaked ½ hr., 2 hrs., 6 hrs., and 24 hrs. respectively in an acetylene solution made by bubbling acetylene through water 30 minutes.

Theoretically, 1·2 g. of pure calcium carbide will produce an effective concentration of acetylene for breaking dormancy in a gallon of water. Commercial calcium carbide is relatively impure, and much gas is unavoidably lost in making a solution. In practice it has been found that 8 oz. of commercial calcium carbide, costing about 6d., will produce enough acetylene gas for 11 gallons of water, which is sufficient to treat 1 cwt. of potatoes at a time. To treat 1 cwt. of seed

potatoes at a time the container would have to be of approximately 16 gallons capacity. It is best to make up a fresh solution for each new batch of potatoes to be treated. Old solution can be re-used provided a small quantity of calcium carbide is added each time a fresh lot of potatoes is placed in it.

In most cases it is best to treat the potatoes whole, as they are easier to handle and losses due to soft rots are minimized. The acetylene treatment itself does not cause rotting of tubers, as soaking in water will lead to breakdown if the potatoes are so infected. Where quick results are required, particularly in very dormant varieties such as Snowflake, it is best to cut the tubers immediately before immersion in the acetylene solution. Cut sets after treatment should be planted at once or suberized on moist sand or bags for 48 hours in a warm place if they are to be held some time before planting.

Where it is necessary to dip tubers for *Rhizoctonia* scab, best results are obtained if this is done after sprouting has been initiated, as the acidulated corrosive sublimate dip depresses sprouting if it immediately follows the acetylene treatment or any other dormancy-breaking treatment, such as thiourea. This depression of sprouting is more marked with whole than cut sets. An objectionable feature in the use of the acidulated corrosive sublimate after any dormancy-breaking treatment with cut sets is the development of mould and discolourations on the cut surface.

Using the commercial method outlined, over 1 ton of potato seed was treated whole at Canberra this year with successful results. This material included dormant Sebago, Katahdin, and Factor. After treatment the tubers were kept in a warm place for a month. The first week following treatment the tubers were kept moist, after which they were dried off and allowed to sprout and green during the remaining three weeks. Sprouting was complete and uniform and the tubers were in good condition for transportation by rail to the planting site.

7. Acknowledgment.

It is a pleasure to acknowledge the help of Dr. Bald, of the Division of Plant Industry, during the course of this work, and his suggestion that a cheap dormancy-breaking treatment was needed for potatoes.

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Note on the Effect of the Acetylene Treatment of Potato Tubers on Potato Moth, *Phthorimaea operculella* Zell.

*By G. A. H. Helson, M.Sc.**

Summary.

The acetylene treatment for breaking dormancy in seed potatoes has no effect upon the development of eggs, but within tubers there is a progressive effect on larvae, most of which are killed after 4 hours immersion in the solution.

1. Introduction.

The acetylene treatment for the breaking of dormancy in seed potatoes, described by Hutton in the preceding article,† has been extensively used in Canberra for the rapid multiplication of mother stocks of virus free strains, as well as for greenhouse experimental work. However, when the treatment was introduced, its effect on the potato moth, *Phthorimaea operculella* Zell., a serious pest in field and storehouse, was unknown, so the following experiments were carried out.

2. Effect as an Ovicide.

Eggs were laid on pieces of muslin by moths kept in glass jars 10 inches high by 8 inches diameter covered with cellophane tops. Some of the eggs were immersed in a saturated solution of pure acetylene in water for varying periods of time, and, after drying, were placed in jars at a constant temperature of 26·7°C. and allowed to hatch. The remainder of the eggs were dipped in water only for 4 hours, and after drying were treated in the same manner. At intervals counts of larvae were made from each set of eggs until no further hatching occurred; then the number of empty egg cases were also recorded. It will be seen from the results in Table 1 that the treatment did not have any significant effect on development or hatching.

Table 1.—Ovicidal Effect of Acetylene Treatment.

Length of Treatment.	Number of Eggs Used.	Number of Larvae Hatched.	Percentage of Larvae Hatched.
3 hours	33	33	100
4 hours	80	77	96
Control	31	31	100

3. Effect as a Larvicide.

From a mass of potatoes 60 thoroughly infected tubers were selected, and were divided into two equal groups, one of which was immersed in water only and the other in a saturated solution of pure acetylene in water. At intervals of $\frac{1}{2}$, 1, and 2 hours, 10 tubers from

* An officer of the Division of Economic Entomology.

† See p. 262.

each group were removed for observation. In another experiment 22 thoroughly infested tubers were divided into two equal lots and treated in the same manner for 4 hours. In both experiments after treatment each tuber was carefully cut and the number of live and dead larvae recorded. The results are tabulated in Table 2.

TABLE 2.—LARVICIDAL EFFECT OF ACETYLENE TREATMENT.

Length of Treatment.	Treated.			Untreated.			Significance.*
	Number of Larvae Alive.	Number of Larvae Dead.	Percentage Dead.	Number of Larvae Alive.	Number of Larvae Dead.	Percentage Dead.	
			%			%	%
½ hour ..	195	13	6·3	189	3	1·6	2·0
1 hour ..	178	43	19·4	177	10	5·4	0·1
2 hours ..	100	80	44·5	256	17	6·2	0·1
4 hours ..	1	37	97·5	19	10	34·5	0·1

The figures show that as the time of treatment increased so the per cent. of larvae killed increased, until after four hours treatment 97·5 per cent. of larvae within the tubers were dead. Application of χ^2 test showed that the differences between the treated and untreated were highly significant in all treatments for one hour or more.

Re-infection of treated tubers readily occurs.

The figures also show that prolonged immersion in water alone kills appreciable numbers of larvae. This is the simplest method of treatment for small numbers of tubers such as are produced in the home garden. Immersion should last for at least 24 hours.

4. Acknowledgment.

Thanks are due to Mr. G. A. McIntyre for statistical analyses.

* The significant values for the difference in proportion of dead to living larvae in the treated and untreated groups were determined by χ^2 test.

A Method of Distinguishing the Commercial Varieties of *T. subterraneum* in the Seedling Stage.

*By K. Loftus Hills, B.Agr.Sc.**

Summary.

The commercial varieties of *T. subterraneum* may be distinguished in the seedling stage by observing the pigmentation of the hypocotyl, the presence of a white area on the juvenile leaf, and the pigmentation of the petiole and leaflets of the first trifoliate leaf.

The ability to distinguish between varieties of *Trifolium subterrancum* in the seedling stage is of importance in seed testing and certification, and in the field where it may be desirable to identify a variety at an early stage.

Amy Myers (†) reported that the early varieties could be distinguished from the mid-season and late varieties of *T. subterraneum* by means of the degree of pigmentation of the hypocotyl two or three days after germination. She observed that seedlings of the variety Dwalganup were larger and darker coloured than those of the variety Mulwala, and suggested that it might be possible to distinguish these two early varieties by measurement of the cotyledons.

During the course of investigations with the species at Moss Vale, N.S.W., certain characters were noted which were found to be of considerable assistance in identifying seedling material. They have subsequently been successfully used in the determination of crosses and similar work.

The tests described below are based on observations of young seedlings sown in soil in flats either in an unheated glasshouse or in the open air. The characters develop progressively from brairding onwards, the final stage generally being reached by the fourth or fifth week after sowing of the seed.

The first distinguishing character appears very soon after the seedlings emerge from the soil. It concerns the presence or absence of pigment on the hypocotyl, and should be noted within a day or so of emergence. The variety Tallarook is free from pigment, and the variety Mt. Barker normally shows only a trace. Other varieties show a wide range of intensity of coloration, Bacchus Marsh being typical of the more heavily-pigmented types.

As soon as the juvenile leaf unfolds, it will be observed that some varieties have a white spot in the centre of the leaf. This may range from a pin point in size, as in the case of Tallarook, to a fairly large crescent in the variety Dwalganup; whereas other varieties, such as Mt. Barker, show no such marking. It is recommended that this observation be made within a day or so of the unfolding of the leaf, although in many cases it may be safe to leave it a week.

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* An officer of the Division of Plant Industry.

† Myers, Amy.—A means of identification of the early varieties of subterranean clover. *Agric. Gaz. N.S.W.*, 50: 376, 1939.

The presence or absence of pigment on the petiole of the first trifoliate leaf is the next character used. Again the observation should be made soon after the appearance of the leaf. Mt. Barker is typical of the non-pigmented group, and Dwalganup of the pigmented group.

The final observation concerns the development of pigment on the leaflets of the first trifoliate leaf, and may take a week or so after the leaf unfolds to develop. Lower temperatures appear to cause more rapid and deeper pigmentation. Some varieties, such as Dwalganup, show no sign of pigmentation, whilst others show characteristic patterns of pigment development. Mulwala has a few minute scattered dark flecks on each leaflet, whilst the pigment on Tallarook, although ultimately very heavy, commences characteristically at the base of the mid-rib of each leaflet as a gradually darkening, rather homogeneous, mass.

The following key uses the characters described above to distinguish between the five commercial varieties certified in the various Australian states. It does not distinguish them from the other known varieties:—

Juvenile leaf without white spot—

Petiole of first trifoliate leaf pigmented .. *Bacchus Marsh.*

Petiole of first trifoliate leaf not pigmented *Mt. Barker.*

Juvenile leaf with white spot—

Leaflets of first trifoliate leaf pigmented—

Hypocotyl pigmented. Pigment of first trifoliate leaf in the form of minute flecking evenly distributed over surface .. .. .. *Dwalganup.*

Hypocotyl not pigmented. Pigment of first trifoliate leaf arising from base of mid-rib as a homogeneous area *Tallarook.*

Leaflets of first trifoliate leaf not pigmented *Mulwala.*

The Reaction of Varieties of *Trifolium subterraneum* to Leaf Rust (*Uromyces trifolii* (Hedw.) Lev.)

*By K. Loftus Hills, B.Agr.Sc.**

Summary.

Data obtained at Moss Vale, N.S.W., show that the reaction to leaf rust of varieties of *Trifolium subterraneum* varies from highly resistant to highly susceptible. Several possible explanations are advanced for the fact that the results obtained at Moss Vale do not agree completely with those obtained elsewhere.

Of the few fungal pathogens which attack *T. subterraneum*, *Uromyces trifolii* appears to be the most serious, particularly in the irrigation districts, where it may occasionally reach epidemic proportions. Little information is available about the disease on *T. subterraneum*, especially in relation to varietal susceptibility. Levy and Gorman (1) classified some twenty varieties of subterranean clover for resistance to leaf rust during plot trials at Palmerston North, New Zealand. They concluded that the latest varieties were the most resistant, and the mid-season the least. Radel (2) in discussing Tasmanian field trials mentioned the relative resistance to leaf rust of several varieties.

Seasonal conditions at Moss Vale, N.S.W., during the late spring of 1941 were such that the growth of the earlier varieties was prolonged, with the result that all the varieties of *T. subterraneum* were at an unusually uniform stage of growth. A heavy epidemic of leaf rust occurred at this time, and spread rapidly through a large variety experiment containing replicated rows of 46 varieties or lots. The opportunity was taken to collect data on infection, marks being given to each of the three plots of each variety according to the scale set out below the table opposite. Seed of many of these varieties was sown under similar conditions at Canberra. A milder epidemic of leaf rust occurred there, and notes† on infection were obtained on one replication of the experiment, using an infection grading very similar to that at Moss Vale.

The table presented below shows the mean rating of infection for each variety at Moss Vale with the standard error, the date of the commencement of flowering for each variety at Moss Vale, the infection rating recorded at Canberra in the same year, the leaf rust resistance estimated by Levy and Gorman (1), and the classification made by Radel (2).

It will be observed that the results are not completely concordant. There is no doubt that under the conditions that existed at Moss Vale during 1941 the variety Tallarook was heavily infected, the scoring of three plots of each of six different commercial lines being reasonably uniform. However, at Canberra it was only attacked to a minor extent, and both Levy and Gorman, and Radel, place it in the resistant group.

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* An officer of the Division of Plant Industry.

† These notes were taken by Messrs. Hely and Hutton of the Section of Genetics, Division of Plant Industry.

THE REACTION OF VARIETIES OF *T. subterraneum* TO LEAF RUST.

Variety.	(I.) Moss Vale (mean of 3 plots). (see key below) 25.11.41.	(II.) Moss Vale Flowering Day, March 1st=60.	(III.) Canberra (single plots) 21.11.41.	(IV.)* Levy and Gorman (1) (heaviest infection 100) 27.4.36.	(V.)* Radel (2) 1935.
Bass	2·0	284	0	3	Resistant
Bacchus Marsh A ..	4·0	253	0	39	Slightly resistant
,, ,, B ..	4·7	263	..	..	
Bena	3·0	276	..	3	
Burnerang A	2·0	269	1	39	Resistant
,, B	4·0	279	..	39	
Daliak	1·0	253	..	29	
Dwalganup A	1·7	238	0	29	
,, B	1·7	239	..	29	
Gingin	4·7	258	5	..	
Kyneton A	3·0	280	0	3	
,, B	4·0	283	..	..	
Macarthur	2·0	272	1	3	
Mt. Barker A	4·3	260	..	100	Very susceptible
,, B	5·0	265	..	..	
,, C	5·0	254	5	..	
,, D	4·0	261	5	..	
,, E	4·7	256	5	..	
,, F	5·0	261	5	..	
,, G	4·7	258	5	..	
,, H	4·3	259	..	..	
,, I	4·0	266	..	..	
,, J	4·3	264	..	..	
Merino	1·3	270	0	..	
Mulwala A	0·0	239	0	29	
,, B	0·0	239	..	..	
Nangeela A	4·3	261	1	39	
,, B	3·7	267	..	..	
,, C	5·0	268	..	..	
Orford	4·3	264	4	100	
Reig. Wh. Seeded ..	1·3	243	..	..	
Romsey	4·0	277	0	3	
Seaton Park	3·3	240	3	..	
Springhurst	2·0	249	..	29	
Second Northam ..	0·0	238	..	..	
Tallarook A	3·7	276	1	3	Resistant
,, B	3·0	273	..	..	
,, C	3·3	277	2	..	
,, D	4·0	275	1	..	
,, E	4·0	278	..	..	
,, F	4·0	277	..	..	
Wallendbeen	4·7	263	4	..	
Wangaratta	3·0	266	1	100	Slightly susceptible
Wenigup A	0·3	272	1	3	Resistant
,, B	0·0	272	1	..	
Yabba North	2·0	243	..	..	
	S.E. 0·28				

Key to Infection Rating in Column (I.).

0. No lesions were observed on any plants.
1. A few lesions were observed on individual leaves.
2. From one to six lesions were observed on many leaves.
3. Heavy infection on many leaves.
4. Heavy infection on all leaves.
5. Very heavy infection on all leaves, with some leaf death.

* Information is not available concerning the source of the varietal lines used by Levy and Gorman and by Radel.

Both Dwalganup and Mulwala varieties showed greater relative infection at Palmerston North than at either Moss Vale or Canberra, and there is definite evidence that at Moss Vale Dwalganup was more susceptible than Mulwala. The variety Bacchus Marsh was heavily infected at Moss Vale, but was not infected at Canberra, and only slightly at Palmerston North and in Tasmania. All four sets of figures agree as to the high susceptibility of the Mt. Barker variety and the resistance of Wenigup.

There does not appear to be any general correlation between relative maturity and leaf rust resistance, although it is possible that the early varieties owe some of their apparent immunity to the fact that their growth had practically ceased at the time of the epidemic. However, significant differences in susceptibility between different lots of the one variety occur in the Moss Vale data. Some of this variation may be accounted for by differences in maturity, but it is possible that actual differences in resistance exist between lines of the one variety.

The apparent variation in the order of susceptibility of some varieties at different places may be due to one or more of the following causes:—

(1) Different physiological forms of the pathogen.

(2) Different lines of the varieties of *T. subterraneum*. However, differences in relative susceptibility at Moss Vale and at Canberra cannot be explained in this manner, as the same lines were sown at both places.

(3) An interaction between conditions of infection and varietal susceptibility.

(4) The relative stage of growth of the varieties when the epidemics occurred. It is not likely that this factor was important at Moss Vale and Canberra as infection took place at a very similar growth stage.

Although some variation occurs, it is evident that the reaction to leaf rust of the known varieties of *T. subterraneum* varies from highly resistant to highly susceptible. This information may be utilized directly by modifying recommendations as to the use of existing varieties in certain districts, or indirectly in breeding varieties resistant to the disease.

References.

(1) Levy, E. Bruce, and Gorman, L. W.—Strain in Subterranean Clover. *N.Z. J. Agric.*, 54: 82-94, 1937.

(2) Radel, L. H.—Subterranean Clover. *Tas. J. Agric.*, 6: 16-24, 1935.

Dormancy and Hardseededness in *T. subterraneum.*

1. The Effect of Time of Harvest and of Certain Seed Storage Conditions.

*By K. Loftus Hills, B.Agr.Sc.**

Summary.

Experiments to determine the effect of delayed harvest on the proportion of dormant and hard seed in subterranean clover were carried out at Moss Vale, New South Wales, in the years 1940, 1941, and 1942. At the same time seed of the species was stored under various conditions to determine their effect on dormancy and hardseededness. It was shown that delaying harvest up to six weeks after the normal stage of maturity caused a considerable reduction in the percentage of both dormant and hard seeds. The storage experiments demonstrated that high temperature, particularly when accompanied by high humidity, was very effective in reducing the proportion of dormant seed.

1. Introduction.

Freshly harvested seed of certain plant species often fails to germinate either because the seed coat is impermeable to water, in which case the seeds are said to be hard, or because the embryo itself is physiologically immature and is incapable of germinating. The latter condition is referred to as embryo dormancy. Many authorities regard hardseededness as a particular type of dormancy, and it seems clear that most of the conditions inhibiting germination are to some extent inter-dependent. The type of dormancy which occurs in *Trifolium subterraneum,* and which is discussed in this paper, is only relative, for no sample has yet been encountered which if left long enough on a moist medium at 22°C. will not germinate. Under these conditions the most obstinate sample had germinated by the fortieth day, and at lower temperature the germination was progressively more rapid.

Toole (6) considers it probable that the seeds of most crop plants show at least a brief period of some degree of resistance to germination. Evidence is available concerning dormancy in certain species of *Triticum, Avena, Hordeum, Festuca, Phleum, Nicotiana, Gossypium, Lactuca,* and several other genera, but the writer has been unable to find any direct reference to the occurrence of dormancy in any species of *Trifolium* other than *Trifolium subterraneum.*

Attention was first drawn to the occurrence of "semi-hard" or dormant seed in *T. subterraneum* by Elliott (3), who found that in 1930, 63 per cent. of W.A. samples contained dormant seed. Woodforde (9) reports the repeated occurrence of dormancy in the species under Tasmanian conditions.

Little is known of the factors responsible for the development of dormancy in the field, but the fact that different lots of the one variety of many species studied show different degrees of dormancy indicates

* An officer of the Division of Plant Industry.

that environment plays an important part. It has been shown in several species of *Gramineae* and in certain other crops that harvest before the seed is mature results in increased dormancy (4, 5, 6, 7, 8).

The experiments reported in this paper were designed to discover the relationship, if any, between the stage at which the seed of *T. subterraneum* was harvested and the degree of dormancy which resulted. At the same time limited laboratory experiments were carried out to determine which if any environmental factors were responsible for the post harvest liquidation of dormancy.

2. Material and Method.

The material for the experiments was grown at the Moss Vale Field Station of the Division of Plant Industry during the seasons 1940-41 and 1941-42.

(i) *Field Experiments.*

Fifty seedlings of the variety *T. subterraneum* known as Tallarook were transplanted into the field in April, 1940. When the material was considered to have reached a stage suitable for harvesting, as judged by general appearance, hardness of the seed, and retraction of the seed coat from the fruit wall, every alternate plant was lifted and the 25 plants thus obtained bulked together before removing the burr by hand. Most of the buried burr came away with the plants. The burr was sampled on a rubber hand thresher. A small sub-sample was taken for a germination test, and the remainder stored in the Moss Vale Field Laboratory. Two months later the remaining plants were harvested and treated in a similar manner to the first group. Germination tests were then carried out on seed samples from both groups. These were repeated at two or three monthly intervals for the remainder of the year.

In 1941 a different method was adopted. Half-chain lengths of each of the varieties Tallarook, Mt. Barker, and Dwalganup were thickly seeded in drills. The material was later divided into sampling units of 1-ft. length of drill row. It was planned to harvest a group of four units selected at random from each variety at fortnightly intervals, but rain caused heavy germination after the sixth sampling in the case of Mt. Barker and Tallarook, and after the fifth in the case of Dwalganup. From the commencement of the sampling until that time only a few points of rain had fallen. The first sample was taken when the seed was immature, at approximately two weeks before the time at which harvest would be considered desirable. The four sub-samples from each variety at each harvest date were kept separate and treated individually throughout. The burr was first removed by hand, and then sampled to give enough burr for two lots of 200 seeds. The first lot was threshed out by finger separation and then tested under normal germination conditions for hard seed content. The second lot was threshed on the rubber thresher and percussed in a special shaker to open up the strophiole before carrying out the germination test. The remaining burr from all samples was stored in paper bags in the laboratory and the above procedure, with the exception of the hard seed tests, repeated simultaneously on 25th of April.

(ii) *Seed Storage Experiments.*

Small experiments to determine the effect of storage conditions on dormancy were carried out in each of the two years. In the first year newly threshed samples of seed of the four varieties, Macarthur, Nangeela, Tallarook, and Wenigup, were stored, (*a*) in red flat closed tobacco tins placed in the field and exposed to the sun, (*b*) in paper packets placed in a germination oven set at 22°C., and (*c*) in packets in a drawer in the laboratory. Samples were removed for germination tests after intervals of approximately 1 month, 3 months, and 6 months. During the 1941 season seed of the varieties Mt. Barker, Tallarook, and Mulwala were stored under known conditions of temperature and humidity. The seed was placed in desiccators containing solutions of salts calculated to maintain relative humidities of approximately 10 per cent. and 80 per cent. at temperatures of 12°C. and 37°C. Samples were removed for germination tests at intervals of 3, 5, and 13 weeks. Two lots of 200 seeds were counted out from each sample, the first lot being tested without scarification or percussion to determine the hard seed content, and the second tested for dormancy after percussion.

(iii) *Germination Technique.*

All germination tests were carried out on moist blotting paper in Petri dishes placed in a germination oven set at 22°C. Additional water was added as required, which was usually at intervals of two or three days. Previous experience in germinating *T. subterraneum* had shown the necessity of ample moisture in the substrate. Work by Aitkin (1) has shown the efficiency of percussion in overcoming the impermeability of the seed coat, and tests by the writer have shown that it is at least as effective as the more usual scarification with sandpaper. It has the advantage of being more easily controlled and of involving somewhat less work. The usual procedure with the dormancy tests was to do an initial separation and count of swollen, hard, and germinated seeds at from 48 to 72 hours after the commencement of the test, and thenceforth at intervals of from one to six days to record the number of additional hard seeds which had swollen, and swollen seeds which had germinated.

Fully after-ripened seed of the species will germinate within 24 hours of swelling, so that the proportion of swollen seeds which have not germinated at any stage may be taken as an index of dormancy.

3. Results and Discussion.

(i) *Field Experiments.*

The percentage of immediately germinable seed in Tallarook plants harvested during 1940 at the normal time, and two months later, is shown in Table 1. It will be observed that at the end of April the original advantage shown by later harvest was still maintained, but that by August the differences were negligible.

The varieties grown in 1941 were assumed to be at their flowering peak about two weeks after the appearance of the first flower. Thus Dwalganup was in full flower by 9th September, Mt. Barker by 6th October, and Tallarook by 16th October. However as far as could

be judged all three varieties reached normal harvesting maturity on 18th December. The first sample had been taken from each about a fortnight earlier.

TABLE 1.—THE PERCENTAGE GERMINATION OF SWOLLEN SEED, AFTER HARVEST OF THE VARIETY TALLAROOK AT THE NORMAL TIME AND TWO MONTHS LATER.

Date of Harvest.	Percentage of Swollen Seed Germinated.		
	Test Commenced on—		
	10/2.*	28/4.†	18/7.†
17th December, 1940 ..	11·9	24·7	90·0
10th February, 1941 ..	34·4	69·6	98·0

* Nine days from commencement of test.
† Eleven days from commencement of test.

The dormancy data from the various harvest samplings are shown graphically in Fig. 1. The curves were obtained by plotting the percentage of swollen seed which had germinated at successive stages of the germination tests, each point representing the mean of four individual sampling units. The initial sampling in the case of all three varieties developed heavy mould when tested immediately after harvest, and the tests were abandoned. However when repeated in April the trouble had disappeared.

Mt. Barker was the most dormant of the three varieties. Material tested immediately after the harvest of 18th December showed a high degree of dormancy, no appreciable germination of swollen seed occurring until after the thirtieth day of the test. However by delaying the harvest a fortnight substantial germination occurred on the sixteenth day of the test. This rapid decrease in dormancy continued until the final harvest on 13th February, 1942. When all the samples were germinated simultaneously at the end of April, every harvest group had decreased in dormancy, but the differences between them were still evident, as may be seen from the curves in Fig. 1 (*b*). The fact that by April the curves for the fifth and sixth harvests were almost identical suggests that little practical benefit was obtained by delaying the harvest after 29th January, 1942.

The curves for Dwalganup and Tallarook in Figs. 1 (*c*)–1 (*f*) show the same general relationship as do those for Mt. Barker. Tallarook was the least dormant but the differences between the various harvests were still distinct and progressive at the April test, although on a very reduced scale. Dwalganup was intermediate in dormancy and the curves in Figs. 1 (*e*) and 1 (*f*) show clearly that with this variety also a definite decrease in dormancy may be effected by delaying harvest for several weeks beyond the stage at which the seed is apparently mature.

In the climatic zone in which subterranean clover is usually grown, evaporation in the early autumn is often very high and the soil may dry out rapidly after rain. Under such conditions it is important

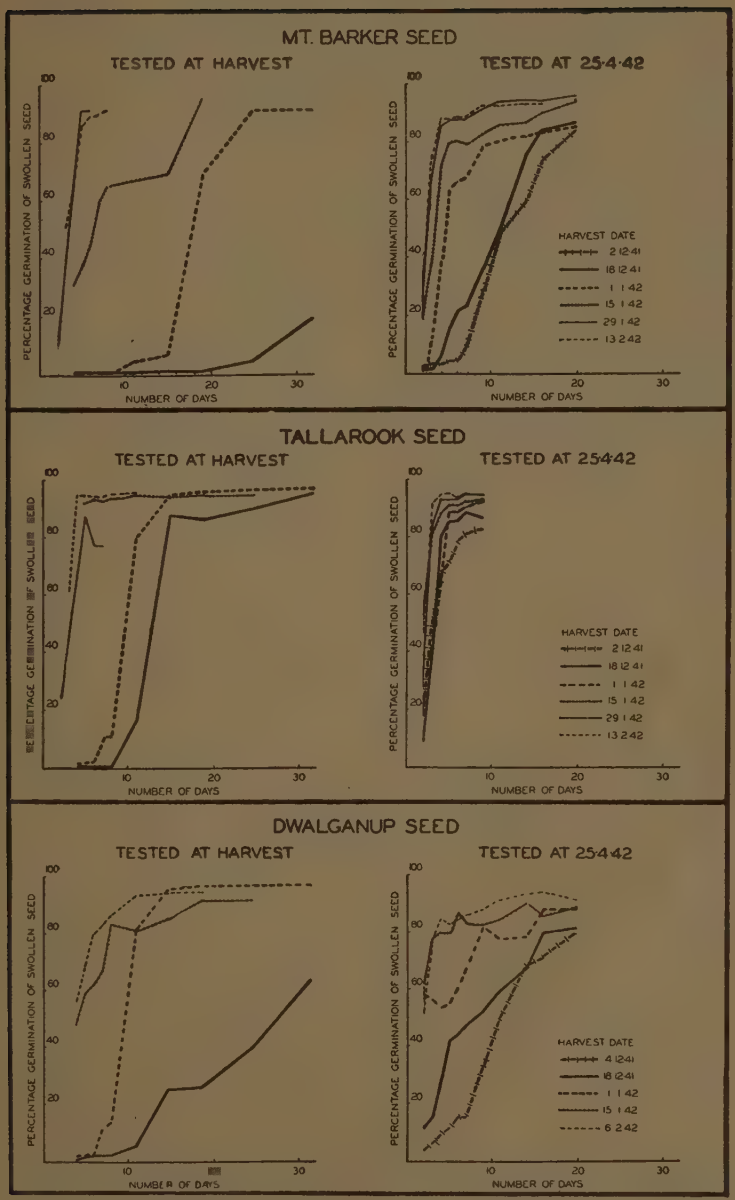

Fig. 1.—The Effect of Time of Harvest of Subterranean Clover Seed upon Delayed Germination.

that seed may be capable of very rapid germination so that the root may reach down to the moisture within only a day or so of a fall of rain. Thus in certain circumstances slight advantages in rapidity of germination might result in disproportional increases in field establishment. Considered from this point of view, such minor differences as are evident in Fig. 1 (*d*) assume greater significance.

(ii) *Seed Storage Experiments.*

Diminution of dormancy with later harvest may be due either to the continuation of translocation of material from the plant to the seed or merely to the effect of the external field environment on the seed itself. In the latter case delayed harvest would be equivalent to storage under conditions which favoured the liquidation of dormancy. The results of storage experiments carried out in 1940 and 1941 are set out in Tables 2 and 3. Although there are one or two unexplained discrepancies in Table 2, it is apparent that storage in closed tins exposed to the sun brought about decreases in dormancy comparable to delayed harvest. Storage in packets in the oven at 22°C. caused

TABLE 2.—THE PERCENTAGE GERMINATION OF SWOLLEN SEED, FOLLOWING STORAGE UNDER THREE CONDITIONS. STORAGE COMMENCED 23/1/41.

Condition of Storage.	Percentage of Swollen Seed Germinated*		
	Removed from Storage—		
	25/2.	28/4.	18/7.
Macarthur.			
22° oven	19·8	31·8	46·2
Tins in sun	49·8	51·8	74·2
Laboratory drawer	17·9	2·0	40·0
Nangeela.			
22° oven	61·9	39·5	72·7
Tins in sun	46·7	76·1	92·4
Laboratory drawer	29·7	11·1	..
Tallarook.			
22° oven	82·7	84·0	73·2
Tins in sun	92·3	91·0	94·7
Laboratory drawer	62·3	26·7	21·1
Wenigup.			
22° oven	57·9	64·8	71·2
Tins in sun	71·5	71·4	78·3
Laboratory drawer	27·8	79·8	..

* Eleven days from commencement of test.

a lesser decrease, but both treatments were much more effective in liquidating dormancy than was the control storage in a laboratory drawer. Table 3 shows the results of storage under controlled conditions of temperature and humidity. The figures are not conclusive, but they suggest that temperature is the most important factor concerned, although the effect of humidity becomes more pronounced as the temperature rises. Such an interplay of temperature and humidity is very similar to that observed during the deterioration of stored seed, and it is interesting to note that when the above experiment was continued for four months such deterioration of seed did occur, particularly at the higher temperatures and humidities. It is quite possible that the ageing of the seed is a continuation of the physiological changes involved in after-ripening.

TABLE 3.—THE PERCENTAGE GERMINATION OF SWOLLEN SEED, FOLLOWING STORAGE UNDER KNOWN CONDITIONS OF TEMPERATURE AND HUMIDITY. STORAGE COMMENCED 9/1/42.

Condition of Storage.	Percentage of Swollen Seed Germinated*		
	Removed from Storage—		
	29/1.	19/2.	16/5.
Mount Barker.			
12°—10%	36·1	59·6	74·4
12°—80%	41·4	74·4	66·3
37°—10%	61·5	85·5	73·3
37°—80%	84·2	82·5	66·5
Tallarook.			
12°—10%	62·3	73·1	97·1
12°—80%	66·9	88·5	88·7
37°—10%	85·2	88·8	92·0
37°—80%	90·0	85·8	82·6
Mulwala.			
12°—10%	3·8	8·0	1·1
12°—80%	0·5	1·1	0·0
37°—10%	2·8	53·2	72·4
37°—80%	45·7	100·0	55·0

* Seven days from commencement of test.

It may be inferred that the effect of delayed harvest is primarily due to exposure of the seed to such conditions rather than to additional translocation effects.

(iii) *Proportion of Hard Seed.*

The proportion of hard seed for the three varieties at each of the 1941-42 harvests is set out in Table 6. The differences between hard seed contents at different harvest dates were significant at the 0·1 per

cent. level for Tallarook and Mt. Barker, and at the 5 per cent. level for Dwalganup. The three varieties at first increased in hard seed content, but later Tallarook and Mt. Barker showed significant decreases. The Mt. Barker figures show that an initial rise in hard seed content took place from 18th December to 1st January, and that this was followed by successive decreases on 15th January and 29th January. With Tallarook the increase was maintained until 15th January, but by 29th January a significant decrease took place. In the case of Dwalganup the initial rise was not followed by a fall.

The effects of the various storage treatments on hard seed content are shown in Tables 4 and 5. The only treatment which produced effects similar to that of continued field exposure was storage in tins exposed to the sun.

TABLE 4.—THE PERCENTAGE OF HARD SEED AFTER STORAGE UNDER THREE DIFFERENT CONDITIONS. STORAGE COMMENCED 23/1/41.

Condition of Storage.	Percentage of Hard Seed*		
	Removed from Storage—		
	25/2.	28/4.	18/7.
Macarthur.			
22° oven	70·5	78·0	80·5
Tins in sun	86·5	72·0	84·5
Laboratory drawer	67·5	75·0	90·5
Nangeela.			
22° oven	79·5	81·0	89·0
Tins in sun	85·0	41·5	40·5
Laboratory drawer	77·0	82·0	..
Tallarook.			
22° oven	58·0	70·0	79·5
Tins in sun	61·0	33·0	34·5
Laboratory drawer	52·0	75·0	90·5
Wenigup.			
22° oven	15·5	46·0	74·0
Tins in sun	59·5	47·0	58·5
Laboratory drawer	18·5	35·0	..

* Eleven days after commencement of test.

The data suggest that field exposure is far more effective in softening hard seed than is the storage of seed under commercial conditions.

These facts may explain why good re-establishment of certain species is often obtained in the autumn following seed formation, when seed

which is harvested and stored in the laboratory may take years to soften appreciably. The initial increases in hard seed content are in agreement with the results obtained by Aitkin (1), and are explained by her in the basis of increased suberization of the seed coat which accompanies dehydration.

TABLE 5.—THE PERCENTAGE OF HARD SEED AFTER STORAGE UNDER KNOWN CONDITIONS OF TEMPERATURE AND HUMIDITY. STORAGE COMMENCED 9/1/42.

Condition of Storage.	Percentage of Hard Seed*		
	Removed from Storage—		
	27/1.	19/2.	10/4.
Mount Barker.			
12°—10%	71·5	76·5	66·0
12°—80%	70·5	72·5	72·0
37°—10%	78·5	73·0	71·0
37°—80%	64·5	63·0	69·0
Tallarook.			
12°—10%	90·0	83·5	87·5
12°—80%	88·0	86·0	76·0
37° 10%	85·5	84·0	86·5
37°—80%	81·5	78·0	80·0
Mulwala.			
12°—10%	82·5	80·0	..
12°—80%	75·0	66·5	71·0
37°—10%	75·0	70·5	75·5
37°—80%	63·0	58·0	67·5

* Seven days from commencement of test.

TABLE 6.—THE HARD SEED CONTENT OF VARIETIES AT DIFFERENT HARVEST TIMES.

Date of Harvest.	Percentage of Hard Seed—		
	Mount Barker.	Tallarook.	Dwalganup.
18th December, 1941 ..	79·0	62·3	84·6
1st January, 1942	92·7	96·6	95·6
15th January, 1942 ..	81·0	96·4	97·3
29th January, 1942 ..	65·3	79·8	..
6th February, 1942 ..	..	..	99·5
13th February, 1942 ..	71·3	76·5	..

S.E. 3.76.%.

4. Conclusions.

(i) The varieties of *T. subterraneum* known as Mt. Barker, Tallarook, and Dwalganup, showed a decreasing proportion of dormant seed when harvested up to six weeks after the stage when they would normally be considered ready for harvest. The differences were still evident, although on a reduced scale, after a further three months' storage in the laboratory.

(ii) Changes in dormancy similar to those resulting from delayed harvest can be brought about by subjecting the seed to high temperatures and humidities.

(iii) When left in the field after the normal harvesting stage, the varieties Tallarook and Mt. Barker showed an initial rise in hard seed content, which was later followed by a distinct and progressive decrease. Dwalganup did not show a similar decrease in hard seed content.

5. Practical Applicatians.

Dormancy in new season's seed of subterranean clover could be reduced by delaying harvest for about six weeks after the crop would normally be considered ripe; at the same time the energy of germination the following autumn would be increased. However, in districts of summer rainfall, such delay is undesirable as summer showers may cause premature germination and the loss of the seed crop.

It may be possible to reduce dormancy of seed commercially by holding it for short periods at temperatures up to 37°C. Care should be taken not to prolong such exposure, particularly if the humidity is high, for such conditions are similar to those which cause rapid deterioration of stored seed once the point of maximum germination energy is passed.

6. Acknowledgments.

The writer has pleasure in acknowledging the help given at all stages of the work by Mr. D. R. Meyer, and the service rendered by Mr. M. Hutton in arranging and supervising the storage experiments at Canberra.

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The Felting of Wool.

*By E. H. Mercer, B.Sc., A.Inst.P.**

Summary.

A method for the rapid determination of the shrinkage of woollen yarns due to felting is described. This method is used to study the effect of the pH and temperature of the felting bath on the rate of felting of yarns of untreated wool and of wools treated to reduce their rate of shrinkage. The results differ in some respects from those of Speakman, Stott, and Chang, and in the particular case of the effect of temperature confirm the finding of Schofield that there is no maximum rate of felting at 45°C.

The nature of felting is discussed in the light of these experiments, and it is suggested that a surface property of the fibres plays the dominant role in felting.

I. Introduction.

The felting of wool has been made the subject of several investigations, but there is still some lack of agreement between the experimental findings. As is natural under these circumstances there is no generally accepted theory to explain the process. In this paper no attempt will be made to give a full account of the work done on the question except when necessary in the interests of clarity. A more complete survey has been made by Boxser (1938). Several names, such as felting, fulling, and milling, are in use to describe processes which produce essentially the same tangling or matting of fibres. The single word "felting" will here be used.

Felting is a peculiar form of consolidation of woollen masses brought about as may be seen by eye by the intimate tangling of the individual wool fibres. A loose woollen cloth is converted progressively by felting into a smaller, compact, relatively inextensible mass of interlacing fibres. The process is of value in the manufacture of felted materials, but on the other hand, since it is also the cause of the irreversible shrinkage of woollen garments, much research has been directed towards preventing or minimizing its effects. The development of shrinkage reduction processes has in recent years revived interest in the felting process.

There is no agreement as to the correct way of measuring the amount of felting. This is not surprising if we look upon it as the amount of disordered tangling produced from an ordered arrangement of fibres. The various properties of fabrics, such as area, thickness, volume, extensibility, and permeability, which change as felting progresses, have all been used as a measure of the degree of felting. In particular the area shrinkage method is much used for assessing the value of shrinkage reduction treatments. All these methods lack accuracy and require inconveniently large amounts of wool and felting liquor. There is need for a quick, simple, and convenient way of estimating the degree of felting.

A method developed by Creely and Le Compte (1940), which makes use of the linear contraction in length of woollen yarn occurring on washing, promises to satisfy these requirements. Owing to the small

* An officer of the Division of Industrial Chemistry, stationed at the McMaster Animal Health Laboratory, Sydney.

amount of wool and felting liquor required, such factors as temperature, pH of bath, and concentration of wetting agents, may be readily controlled. One measurement suffices to give the percentage shrinkage, and distortion, which is very troublesome when using the area shrinkage method, does not come into account.

In the course of work carried out in the development of a shrinkage reduction process (Freney and Lipson, 1940), we have devised a method almost identical with that described by Creely and Le Compte. This paper will describe the use of this method to study the effect on felting of such variables as the pH and temperature of the felting liquor, which have assumed theoretical importance. Other properties of the wool fibres themselves are known or have been thought to influence felting, but for a discussion of these the reader is referred to papers by Speakman, Stott, and Chang (1933), and Boxser (1938). The present investigation concerns only the effect of the felting liquor on the rate of felting of untreated wools and wools treated by two unshrinkable processes.

2. Description of Apparatus and Method.

The apparatus resembles that described by Creely and Le Compte. A cylindrical bottle, 3 in. in diameter and 4 in. high, closed by a lid, was mounted on a specially constructed shaking machine. The motion of the bottle was horizontal and linear; the frequency of oscillation 280 p. min. Yarn lengths about 105 cm. long with a metre marked off on them were placed with the felting solution in the bottle. One or more hard rubber balls 1 in. in diameter could be added to increase the rate of felting. The bottle was heated electrically by means of a coil of wire wound externally. Hand control of the current was found sufficient to maintain the temperature within suitable limits as the time of shaking was only two minutes between measurements.

The rate of felting is affected by a variety of factors, which must be carefully standardized: shape of bottle, amplitude and frequency of oscillation, number and shape of balls, number and length of yarns, amount of felting liquor. Unless otherwise stated, six 1-metre lengths of 3/16's 60's quality yarn and one rubber ball were used in these experiments.

The yarn lengths were measured by soaking yarns for several hours in distilled water to relax set, and stretching them against a ruler by means of a weight of 2 g. A careful procedure in measurement is necessary to obtain reproducible results. The yarns after washing are unravelled and remeasured in the same way. It was found advisable to unravel and measure at the end of each two minutes' washing. This prevented tangling among the yarns and favoured more uniform felting along the yarn length.

Three washes of two minutes each produce shrinkages of the order of 50 per cent. This may be compared with the 100 minutes required by Creely and Le Compte, and five hours by Speakman, Stott, and Chang (1933), to produce shrinkages of the same order. The method is simple and convenient, and permits a degree of control of variables not readily obtained in methods using commercial felting machines.

Is the yarn length shrinkage produced in this way a reliable criterion of felting? There is no generally accepted criterion of felting and the uncertainty is partly one of definition. In the absence of a

clear definition of felting, investigators are obliged to use variations in some property of woollen yarns or fabrics, which changes with felting, as a measure of the amount of felting. An examination of a yarn shrunk by this method shows clearly that felting is the cause of the decrease in length. Yarn length shrinkage is in fact more directly and simply related to fibre tangling than the change in cloth area or thickness, more commonly used. The best recommendation of the method is its convenience for large numbers of tests. Creely and Le Compte (1940) found that there is a correspondence between yarn and fabric shrinkage sufficiently close to enable yarn to be used instead of cloth for shrinkage measurements. By comparing their results with those of Speakman, Stott, and Chang (1933), they hoped to show that a strict relation existed between yarn and fabric shrinkage. In this they were only partly successful. No attempt will be made here to correlate the two forms of shrinkage, because no simple relation is to be expected. This will be clear if it is recalled that from the same yarn may be knitted or woven a variety of cloths having different feltabilities on account of the different degrees to which fibre tangling is hindered in the various cloths.

3. Experimental.

(a) Felting as a function of pH of the felting liquor.

The percentage yarn shrinkage was determined at the temperatures 18°, 25°, and 40°C. in the pH range 1–11 in steps of about 0·4 pH unit, after 2, 4, and 6 minutes' washing. A definite pH value during washing can be maintained only by the use of buffers; on the other hand a salt concentration alters the amount of acid and base bound by the wool (Steinhardt and Harris, 1940) and also the rate of felting. This difficulty was partly met by using buffers with a salt concentration as low as was found compatible with the desired pH stability. The possibility of specific effects arising from the particular salts used remains in some cases. Clarke and Lub's buffer mixtures were used diluted once with distilled water and supplemented by others described by Michaelis (1926) for the range beyond 10. The mixtures were checked with a glass electrode (*a*) before wool was introduced, (*b*) after standing for 12 to 16 hours, to enable equilibrium to be reached, and (*c*) after they had been used for the washing operation. The average of (*b*) and (*c*) was taken as the pH of the washing mixture unless the difference was more than 0·2 pH unit, when the experiment was repeated. The pH values given were measured at 25°C., but in most cases the pH of these buffers is little altered by temperature and no effort was made to correct the figure obtained at 25°C. to the washing temperature.

The temperature was maintained constant to within ± 1°C. at 18°C. and 25°C. and ± 2°C. at 40°C.

Six 1-metre lengths of 3-ply yarn were used in each experiment: four lengths of untreated wool and one each of wool treated by means of the alcoholic alkali process, developed by Freney and Lipson (1940) and patented by Hall and Wood (1939), and the sulphuryl chloride process (Hall, 1939) respectively. The shrinkage of the four yarns of untreated wool usually agreed to within 4 per cent. of the original length. A rather lower order of accuracy is admitted in the case of the treated wools, since only one of each was included and unevennesses often occur in treatment.

The results are tabulated below (Tables 1, 2 and 3), and partly set out in Figs. 1 and 2.

TABLE 1.—PERCENTAGE YARN SHRINKAGES AT 18°C.
(6 minutes' washing.)

pH.	Untreated.	Treated by the Alcoholic Alkali Process. (Freney and Lipson, 1940.)	Treated by the Sulphury Chloride Process. (Hall, 1939.)
1·4	41·0	31·5	5·5
1·6	30·0	24·0	4·7
2·15	28·0	26·0	3·0
2·6	26·0	..	4·2
2·7	25·5	..	4·7
3·1	23·5	18·0	2·5
4·15	21·5	19·0	3·5
5·1	19·5	16·0	5·0
5·9	19·0	17·0	5·0
7·1	..	10·2	5·5
7·5	18·5	12·0	6·65
7·65	17·5	11·5	6·0
8·2	17·0	11·0	6·5
9·05	17·5	11·3	5·0
9·3	18·6	12·0	6·5
9·65	17·5	7·3	4·5
9·95	16·3	7·3	4·5
10·1	17·2	9·0	4·5
10·3	21·0	11·0	..
10·4	23·0	13·5	..
10·5	21·5	13·0	..
11·1	23·5	13·0	5·5
11·6	21·5	11·0	5·5

TABLE 2.—PERCENTAGE YARN SHRINKAGES AT 25°C.
(6 minutes' washing.)

pH.	Untreated.	Treated by the Alcoholic Alkali Process.	Treated by the Sulphuryl Chloride Process.
1·4	56·0	33·0	15·0
2·0	55·0	35·0	15·0
2·6	47·0	31·0	11·6
2·9	42·0	27 0	14·0
3·0	{ 42·5 41·5 }	25·0	11·0
3·4	41·0	..	..
4 3	37·0	22·0	13·0
4 4	37·0	..	..
5·2	33·0	21·0	15·0
5·8	33·0	18·0	15·0
7·3	31·0	12·0	14·0
7·8	28·5	10·0	12·0
8 2	28·0	8·0	12·0
8·4	28·0	8·0	12·0
9·0	24·0	9·0	10·5
9·4	25·0	9·5	9·5
9·6	25·5	11·0	9·0
9·8	29·0	11·0	8·0
9·9	31·0	12·0	7 5
10·6	28·0	10·0	7·0
10·9	24·0	9·0	7·0

TABLE 3.—PERCENTAGE YARN SHRINKAGES AT 40°C.

(6 minutes' washing.)

pH.	Untreated.	Treated by the Alcoholic Alkali Process.	Treated by the Sulphuryl Chloride Process.
1·8	59·5	42·5	30·0
3·0	50·0	39·5	28·0
4·2	50·0	38·2	23·0
4·9	50·0	38·0	22·0
5·95	42·0	34·0	20·0
7·15	38·5	27·0	14·0
7·95	38·2	25·5	13·0
8·95	39·0	26·0	16·0
9·6	38·0	26·0	16·0
9·9	41·0	30·0	16·0
10·15	44·4	33·5	18·0
11·0	43·0	32·5	16·0

TABLE 4.—TEMPERATURE AND YARN SHRINKAGE.

pH.	Temperature.	Normal. Time =			Treated by the Alcoholic Alkali Process. Time =			Treated by the Sulphury Chloride Process. Time =		
		2 mins.	4 mins.	6 mins.	2 mins.	4 mins.	6 mins.	2 mins.	4 mins.	6 mins.
4·0	20°C.	12·2	24·0	32·8	4·0	8·8	12·0	6·1	11·7	20·8
	30	20·3	37·1	46·6	8·2	16·1	19·3	5·5	15·0	24·3
	40	24·3	41·0	52·1	10·0	19·1	26·0	7·2	14·6	22·0
	50	27·6	44·5	56·0	11·9	20·0	26·7	9·7	19·3	20·5
	60	29·1	45·7	57·5	10·1	16·3	20·3	7·0	13·5	20·3
7·2	20°C.	9·2	18·9	25·6	5·0	11·0	14·6	3·1	6·3	9·0
	30	11·7	24·0	31·4	7·6	12·1	18·2	3·0	6·8	11·6
	40	15·4	28·2	38·0	8·6	16·1	22·3	3·7	9·4	15·0
	50	18·5	31·7	42·5	9·5	16·1	20·6	5·0	9·2	13·2
	60	22·8	35·8	46·2	5·1	13·0	17·0	6·1	9·0	10·5
9·2	20°C.	6·2	14·1	19·8	5·8	9·0	11·0	1·5	3·8	6·3
	30	12·0	24·0	34·6	8·2	14·0	19·1	2·5	6·5	10·0
	40	14·3	29·5	39·1	9·0	14·0	20·1	2·7	5·0	11·8
	50	16·2	27·9	43·2	6·3	10·0	14·5	2·5	5·0	8·6
	60	18·5	35·0	45·0	5·6	9·3	10·4	2·2	6·0	9·3

UNTREATED WOOL ONLY.

pH.	Temperature.	2 mins.	4 mins.	6 mins.	8 mins.
10·8—11·0	20°C.	10·0	19·0	26·5	33·2
	30	14·0	24·5	32·3	38·4
	40	18·7	32·8	33·0	43·3
	50	76·0	42·0	54·0	53·0
	60	31·0	50·5	64·0	63·0
	70	Too heavily felted to untangle.			

(b) Felting as a function of the temperature of the felting bath.

The shrinkage of yarns was determined for a range of temperature from 20°C. to 70°C. at several representative pH values, viz., 4·0, 7·2, 9·2, and 10·8 to 11·0. The results are tabulated in Table 4. In some cases the felting at higher temperatures (70°C.) was so rapid that the yarns could not be unravelled for measurement. Figs. 3 and 4 serve to illustrate the important features of these results.

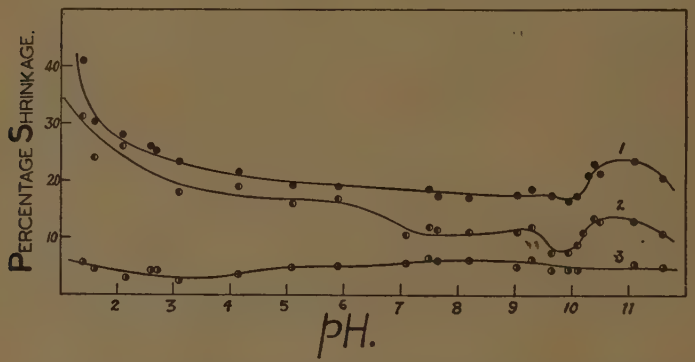

FIG. 1.—The relation between the percentage shrinkage in yarn length and pH of the felting solution at 18°C. (1) normal or untreated wool: (2) wool treated by the alcholic alkali process (Freney and Lipson, 1940): (3) wool treated by the sulphuryl chloride process (Hall, 1939). The positions of curves (2) and (3) relative to curve (1) depend to some extent on the degree of treatment.

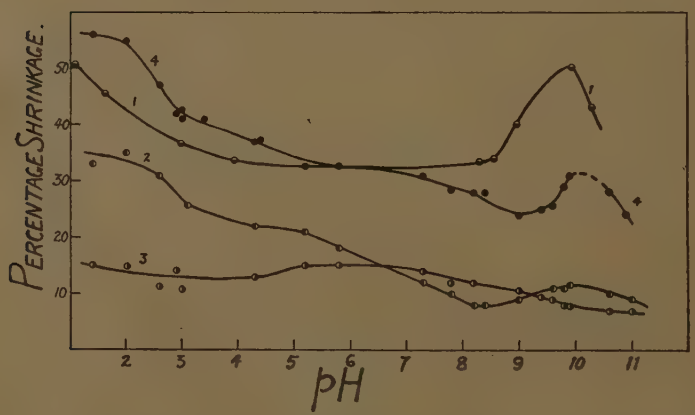

FIG. 2.—The relation between percentage shrinkage and pH at 25°C. (1) normal wool: (Speakman, Stott, and Chang, 1933; see text), temperature not given; (2) alcoholic alkali treated wool; (3) sulphuryl chloride treated wool; (4) normal wool by present method.

4. Discussion.

The accepted theory of felting, advanced in part by Shorter (1923) and Arnold (1929) and developed by Speakman and Stott (1931), and Speakman, Stott, and Chang (1933), is that felting arises from the uni-directional (rootwards) migration of each individual wool fibre in a fabric or yarn. This migration may be demonstrated by experiments in which dyed fibres are included in pieces of woollen fabrics. Arnold conceived the fibres wriggling forward with a worm-like movement, but the dynamics of the motion was not made clear. Speakman, Stott, and Chang (1933) considered that, in general, felting was facilitated by conditions which increased the extensibility of fibres, and was reduced by conditions which decreased extensibility or recovery after extension. This suggests that the migration of fibres is brought about by extension and subsequent contraction, tightening occurring during contraction. These conclusions were based mainly on the results of their study of the rate of felting as a function of pH and temperature of aqueous felting baths. They used as their criterion of felting the area shrinkage of cloth.

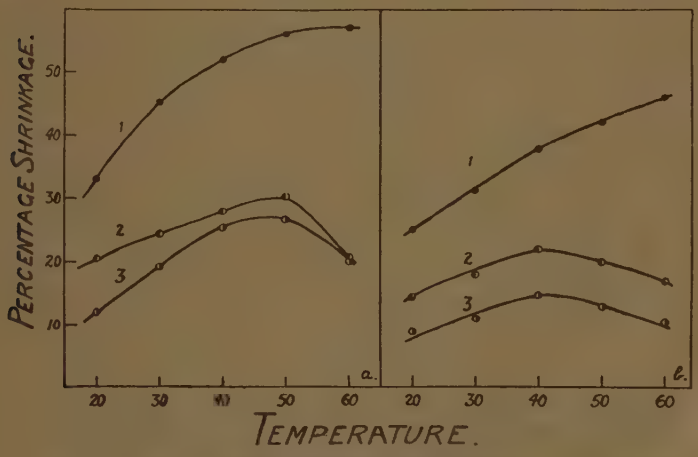

FIG. 3.—Relation between percentage yarn shrinkage and temperature. (1) normal wool; (2) alcoholic alkali treated; (3) sulphuryl chloride treated. (*a*) At pH 4·0, (*b*) at pH 7·2.

The relation found between felting and pH in the experiments described in this paper is similar to that found by Speakman, Stott, and Chang, but there is one important difference. These workers reported that the rate of felting, like the work required to stretch fibres 30 per cent. of their original length, was independent of pH in the iso-electric range of wool (approximately pH 3–8). We have failed to confirm this finding. As may be seen from Figs. 1 to 3, the rate of felting decreases as the pH increases and reaches a minimum value between pH 9 and 10. A curve drawn from the data of Speakman, Stott, and Chang is included in Fig. 2. These same workers drew more important conclusions concerning the role in felting of fibre elasticity and recovery and also of fibre swelling, from the results of

their study of the relation between felting and temperature. Using a small milling machine and a felting liquor containing a potash soap, they found that the felting rate reached a maximum at 45°C. From the more extensive data obtained in the present series of experiments, it is clear that, over a wide range of pH values, felting of wool not treated to reduce felting increases from 20° to 60°C. This is in agreement with the opinions expressed by Schofield (1938).

If felting is dependent on pH in the iso-electric range, in the way shown in Figs. 1 and 2, some factor other than fibre elasticity is changing progressively with pH and is influencing the rate of felting. Whether the marked increase in rate at low pH values and beyond the minimum point is to be ascribed to changes in this same factor and/or increased fibre extensibility, cannot be deduced from the data on felting alone.

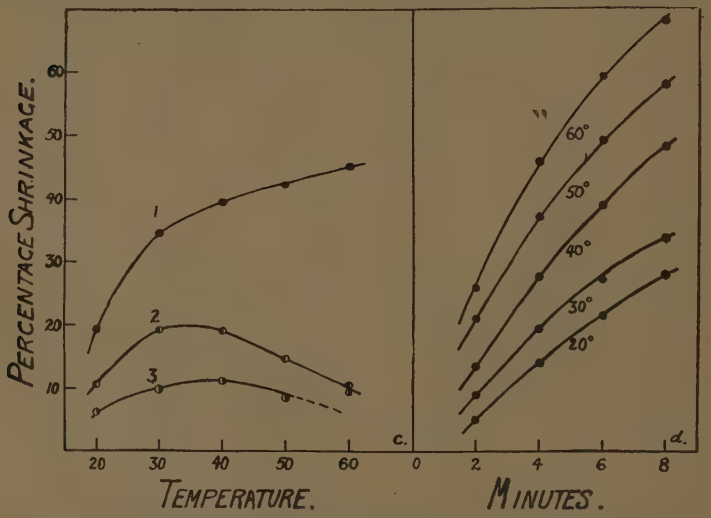

FIG. 4.—(c) Relation between yarn shrinkage and temperature at pH 9·2. Numbering as for Fig. 3. (d) Relation between time of washing and percentage yarn shrinkage at several temperatures for normal wool. pH 10·8—11·0.

Changes in extensibility and recovery power of fibres lead to a minimum in the hysteresis work loss for a cycle of 30 per cent. extension followed by contraction in the neighbourhood of 40°C. The maximum rate of felting found by other workers at 45°C. was therefore regarded as evidence that both stretching and contraction of fibres occurred in felting. On the other hand the definite proof that there is no maximum between between 20° and 60° may be taken to mean either (*a*) that extension does not occur, or (*b*) that extension occurs without recovery, or (*c*) some other factor actually controls the variations in felting rate.

Other properties of fibres are known to affect the feltability of wool. The most important of these is the directional frictional property, sometimes called the "scaliness" or fibres, i.e., the property of being rougher in the tip-root direction than in the root-tip. This is thought to be

the cause of the uni-directional migration of fibres during felting. Although little is known of the dependence of the directional friction on the pH and temperature of wetting solutions which would justify the assumption that variations in this property could account for the changes in felting rate, there is some evidence that the interaction between fibre surface and felting solution is of more importance than previously thought. For instance, when yarns are washed immediately after immersion in a buffer, the shrinkages obtained are almost as large as when the wool has previously been allowed to come into equilibrium with the solution by standing for 16 hours (see Table 5). Washing is completed in 6 to 7 minutes by the present method, and it takes some hours for fibres to come to equilibrium at any pH. Therefore simply wetting and partial penetration has to a large extent determined the amount of felting. The effect of wetting agents (Creely and Le Compte, 1940) and soap, which produce effects distinct from the pH's of their solutions, similarly indicates the importance of some relation between the fibre surface and the solution.

TABLE 5.

Comparison of rate of felting of yarns conditioned in washing solution and yarns merely wetted by the washing solution :—

(*a*) Air dry wool placed in washing solution immediately prior to washing.

(*b*) Conditioned in distilled water for 24 hours and placed in washing solution immediately prior to washing.

(*c*) Conditioned 24 hours in the washing solution.

pH.	Shrinkage* (Average of two yarns.).		
	(*a*)	(*b*)	(*c*)
3·0	37·8†	39·6	39·7
9·2	23·2†	23·3	24·0

* Six minutes' felting at 24–25°C.

† Yarns shaken dry would scarcely felt at all, although the elastic properties of their fibres would be very similar to those of (*a*).

The considerable changes produced in the relation between felting pH and temperature by the purely superficial attack of certain reagents used in shrinkage reduction processes, tends also to emphasize the importance of the relation between fibre surface and solution. The relation between felting rate and pH exhibited by wool treated by the alcoholic alkali process resembles in broad features that of ordinary wool. Between pH 7–10, however, feltability is reduced, and the minimum point appears to occur at the same pH as for normal wool. The rate of felting has a maximum at 40° to 50°C., varying with pH. As may be shown by comparing stress-strain curves for fibres in various buffers before and after individual treatment, the elastic properties of the fibres are indistinguishable from those of normal wool. The treatment has altered the dependence of the felting properties on pH and temperature without change in elastic properties. The time of treatment is too short to allow appreciable penetration of either alcohol, water,

or hydroxide into the fibre. Experimentally this can be shown by elastic experiments on fibres immersed in the treatment liquid. Treatment with sulphuryl chloride is known (Hall, 1939) to produce changes in fibre elasticity, but the reduced feltability of sulphuryl chloride treated wool is usually ascribed to a surface change.

These arguments are by no means final, but they at least suggest (*a*) that the elastic properties of fibres do not play the dominant role in determining the feltability of wool in aqueous solutions, and (*b*) that the surface of the fibre, perhaps the directional friction of the fibre surface, may prove to play an important part. Direct experimental evidence on this point is still lacking.

Speakman, Stott, and Chang (1933) rejected the view that fibre swelling could immediately influence felting, because swelling decreases until 32°C. and thereafter increases, whereas they believed felting to reach a maximum at 45°C. The same conclusion may be drawn from the present work, since there is no anomaly in the felting-temperature relation at 32°C.

5. Acknowledgments.

I wish to thank my colleagues, Messrs. M. R. Freney and M. Lipson, for their help in discussion.

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Agar-agar Manufacture.

*By E. J. Ferguson Wood, B.A., M.Sc., A.A.C.I.**

Several preliminary reports on aspects of agar production in Australia have been published in this *Journal* and in the *Fisheries Newsletter,* but the main work is still unfinished and the results of it therefore unpublished. As there seems to be a desire for a statement of the present position and as the full report will not be in press for some time, a summarized statement is given in the paragraphs that follow.

1. The Market.

Prior to the war, Japan produced from about 2,000,000 to 4,000,000 lb. of agar-agar by primitive means, and the price varied from 3s. per lb. upwards, inversely as the severity of the winter. America had an industry which is reported to have produced 300 tons per annum, though this figure has not been confirmed. Russia had a steadily expanding production of agar and agaroids but was not self supporting in this respect. America imported about 300 tons per annum, Britain about 200 tons, Australia 70 tons, and New Zealand 15 tons. The present price of agar is 25s. per lb. or $4·25, and stocks are being depleted.

2. The Australian Industry.

One Australian firm is producing its own requirements for meat canning, one firm is close to production on a commercial scale, and two firms are engaged in laboratory experiments. All these are in Sydney, but there has been some interest shown by firms in Western Australia and Queensland. No dried agar has yet been produced for a rather clamorous local market.

3. The Raw Material.

Although several seaweeds have been found suitable for agar-agar production, notably *Gracilaria confervoides?, G. lichenoides, G. furcellata,* and *Euchyeuma spinosum, G. confervoides* is the most abundant and will probably be the main one used. This weed grows on sandy flats in about 15–20 feet of water, and a bed may be anything up to 2 feet deep.

The total possible production of agar in Australia cannot be assessed, but local estimates may result from noting the effect of harvesting and the amount of seaweed which a given area will yield in a year with organized collection of seaweed. It will be necessary to make periodical examinations of each estuary as there is evidence of great variation. For example, in 1941, Port Hacking yielded a small amount of seaweed from well defined beds, but, though only a light harvesting was made and no weed came ashore, there is very little *Gracilaria* on those beds in 1942. Alterations in the bottom of the area have resulted in a completely altered distribution of weed

* An officer of the Division of Fisheries.

growth. The beds harvested to some extent at Bateman's Bay are not affected, though they share with the untouched beds in Botany Bay a very much delayed growth period. The fact that, even if the weed is not washed ashore at all, it still disappears from the beds at the close of its growing period, makes it desirable that collection from the actual beds should be attempted. Moreover, very pure seaweed can be obtained in this way, as *Gracilaria* does not mix with other weeds as a rule.

In areas where the weed is washed ashore in quantity, much of it is buried in sand and lost. It seems advisable to erect fences about 4 feet below low tide level to keep the weed from reaching the beach. It would hang in front of the fence and harvesting would be extremely easy. This, and collection from the actual beds, should minimize the loss of seaweed.

Tests are being made in order to see whether it is possible to plant *Gracilaria* in suitable areas. The results will be important, as, if successful, they will allow the effect of harvesting to be determined.

Drying tests on harvested material show that the weed can be most easily dried on wire racks, but evidence tends to show that bleaching is easiest on grass. Artificial drying was not particularly successful. The weed was dried in a warm kiln with natural draught, and in a tunnel drier with fan draught and partial recirculation. Both took 24 hours, and a similar quantity dried in air took 48 hours. The artificially dried weed had less moisture at completion of drying, but after 24 hours exposure to the atmosphere the moisture content of all samples was the same. Artificial bleaching with chlorine was effective but reduced the gel strength of the agar.

Natural bleaching by sun, rain, and dew gives a very desirable product, but seriously increases the cost of preparation. In laboratory scale experiments, two days were required to dry the seaweed and 16 days for bleaching. The weed has to be spread thinly (not more than an inch in depth) and turned at least every second day. This means a large drying ground and actually more labour than harvesting and drying. At the resultant agar from dark weed is not particularly dark in colour at the gel strengths used, it is considered that bleaching is unnecessary in war-time. Bacteriological agar might be filtered with carbon, but even this is not obligatory as it has been shown that growth factors etc. present in agar are removed by excessive purification. Although golden yellow or greenish in colour when dry, unless bleached with carbon, Australian agar gives a more transparent gel than Japanese agar and appears more elastic, though dry Japanese agar is white. In view of these facts and of the labour shortage, buyers should be content with the golden agar, which is much more easily produced under our conditions.

The price paid for the raw material has varied from £25 to £75 per ton. The latter price is encouraging to collectors and should still allow manufacturers a good margin of profit even if agar falls to half its present value, as is possible when production is moderately large. As the industry grows, the price of the raw material will no doubt stabilize itself, and it must be recognized that after the war it will probably fall to about £40 per ton. If the agar is bleached by

activated carbon prior to filtration, it may be found possible to lower the cost of collection still further and produce a high grade product. In this way it should be possible to compete on the world market at the pre-war price of agar.

4. The Manufacturing Process.

The process described is that which has been found to give best results in this laboratory, both in laboratory scale and pilot plant experiments. Manufacturers will naturally adapt the process to suit their own requirements and the plant available.

1. The weed is sampled as follows:—Small representative samples are taken and placed on white paper. The sand and other inorganic matter are shaken out and weighed. Next, other seaweeds are removed and weighed and the amount of inorganic and organic impurities is calculated, the moisture content of the *Gracilaria* is determined, and the seaweed is extracted three times for 2 hours with live steam, 10 grammes of weed being heated at 95–98°C. with 250 ml. of water. Aliquots are taken from each extraction and added while still warm to a five-fold volume of alcohol. The precipitate is filtered through a tared filter and weighed, and the per cent. pure agar calculated. Alcohol is a precipitant for agar. The laboratory can thus indicate the quality of the seaweed and the probable yield of agar.

2. The seaweed is washed with beaters for 10 minutes to 30 minutes to remove sand and other impurities, and is then cut up in a mincer or chaff-cutter, and transferred to the cookers. A counter current or diffusion battery system of cookers is recommended, and live steam should be used to cook the weed at a temperature of 95° to 98°C. The seaweed should be in proportion of not more than 4 per cent. to the water used, otherwise boiling and filtration troubles will be encountered. The pH should be adjusted to 5·0 to 6·0 and kept in this region. Usually 2 to 4 hours will suffice for extraction, but this depends on the efficiency of the boiling plant. Longer times tend to produce partial hydrolysis and a decreased yield.

3. The hot liquor should then be run through a centrifuge of high sludge capacity or with continuous sludge removal. This removes very efficiently the liquor adhering to the solids and is the easiest method of removing the solids from the liquor. Unfortunately, suitable centrifuges are difficult to get, and steam heated bag filters or other means may have to be used. Some success has followed the use of wire baskets with fine gauze screens on the inside. The weed is placed in these baskets in the vat and, after boiling the liquor is run off from the vat itself.

From the centrifuge the liquor is run into a steam jacketed or coil heated tank, and (preferably) activated carbon added and allowed to act. The agar liquor is then cleared by a plate and frame press with the addition of filter aid. A brilliant and colourless liquor should result. This will contain 1·0 to 1·5 per cent. agar and may be concentrated at low temperature *in vacuo*. Care must be taken as overheating will cause hydrolysis and resulting loss of agar.

4. The liquor is allowed to set as a gel either in ice cans or in slabs and is frozen either in brine or in air as equipment permits. Low temperatures cause homogeneous freezing which is undesirable. A

useful temperature is 21°F., where freezing is effective and reasonably rapid. The purpose of freezing is to remove organic impurities which cannot be removed in other ways. It is found that the gel strength increases 4 to 6 times and that this increase cannot be obtained without freezing unless other more expensive methods are used.

5. The agar-ice is thawed out in water at about 35°C. and washed in running water. It can be crushed first in an ice crusher or else chopped up after thawing, when it separates as a crepe-rubber-like mass.

6. This agar can be dried in various ways. In the laboratory a tunnel drier has been used at 40–50°C., but drum drying is practised on an analogous product in Russia. Spray drying has been suggested and there seems to be no reason why it should not work. It would give a powdered agar which is much desired.

5. The Quantities Involved in Manufacture.

1. It can be reckoned that 1 ton of dried dark *Gracilaria* will be produced from 7 tons of wet drained seaweed, and 1 ton of clear bleached *Gracilaria* from 8 tons of wet drained seaweed. Under present harvesting conditions one man can harvest, dry, and bleach the equivalent of about 1 cwt. of dry bleached weed per day. On many days he may be unable to harvest, but it will pay to collect and dry seaweed in the season and bleach it, if required, in the off-season.

2. Stored *Gracilaria* if properly baled will occupy about the same space as an equal weight of wool or probably slightly more.

3. The weed is boiled in 4 per cent. solution, and the yield may be computed conservatively at 33 per cent. Therefore 1 ton of agar will require the boiling of 3 tons of seaweed and 75 tons of water for the first boiling, and 50 tons for a second boiling (if a second extraction is made). Each boiling would be from 2 to 3 hours. The vats would need to hold about 15,000 gallons of water in all.

4. The centrifuges would have to deal with 15,000 gallons per day with 2 tons of sludge. The filters and evaporators would also have to carry 15,000 gallons, and this might be reduced to 10,000 gallons for freezing, or 50 tons of material to be frozen.

5. Drying: Tunnel or room drying. The frozen agar may be regarded as a 10 per cent. solution, i.e., 90 per cent. water to be removed. Spray or drum drying would require to remove nearly 98 per cent. water. The sale price of powdered agar is always considerably higher than strip or flake agar, and powdering would remove the disability of the colour of Australian agar, as powdered agar is always brownish.

6. The Product.

As indicated above, Australian agar is different in colour unless bleached with carbon, and, whatever the method used in manufacture, will be different in form from Japanese agar. It has still wider differences in properties. Its elasticity is somewhat greater, and its gel strength appears to be greater at higher concentrations, and less at lower concentrations than Japanese agar. The gel produced is more transparent than that of Japanese agar, syneresis seems relatively

greater resulting in a more slimy feel. Australian agar gives an excellent gel in canned meats, rather preferable to that of Japanese agar, and is also very suitable for confectionery and for bacteriological media. This information is from firms using agar of their own manufacture for commercial production, and in the case of bacteriological agar from results obtained by Professor Ward and Dr. H. L. Jensen of the Bacteriology Department, University of Sydney, by the bacteriologist of a firm making milk products, and by myself.

7. Conclusions.

There is, at the moment, an urgent demand for several hundred tons of agar. Australia is in a position to make a considerable contribution to this shortage, and should, at least, supply the essential needs of the United Nations. With the development of the industry as a war measure, and with the prices obtainable for agar, it should be possible to write off the capital cost and to be in a position to continue economical production after the war. This estimate of the position is made on the basis of existing methods. Short cuts, improvements, and new methods should further decrease the cost of production, while the dependence of an unsaturated market on a single source of supply (Japan) will cease. It will be to the interest of agar users to keep the Australian industry in being to offset shortages due to poor seaweed growth or to mild winters in Japan and to break the Japanese monopoly of the market. The fact that Australian agar is not inferior, and for some purposes is superior, to Japanese agar, seems to ensure a future for the industry.

The possible size of the industry cannot be estimated until production stimulates a search for suitable seaweeds, but it is known that a reasonable amount can be produced from sources close to Sydney, and there is no reason to believe that these sources represent the total material available.

Potato Virus X: The Average Severity of Strain Mixtures in Three Varieties of Potato.

By J. G. Bald, M.Agr.Sc., Ph.D. and N. H. White, M.Sc.**

This paper outlines a portion of the programme of work designed to increase the efficiency of seed potato production by reducing losses due to the latent virus known as virus X. Although stocks of two varieties —Up-to-date and Tasmanian Bismarck—have been obtained free from all virus infection, it may not be possible immediately to obtain virus-free stocks of all varieties. The methods of developing and maintaining stocks of seed potatoes carrying only the mildest strains of virus X are therefore being investigated because mild strains reduce the yield much less than the strains ordinarily carried in commercial stocks. The results of the work outlined here suggest the need for more frequent selection than has been practised.—Ed.

Summary.

A rapid method was evolved for the inoculation of virus X from potato tubers. The tuber itself was used both as a source of inoculum and an instrument for inoculation.

Populations of virus X strain mixtures carried in different lots of the same potato variety were similar.

There were wide differences in strain mixtures carried by the three varieties.

The hypothesis of a natural equilibrium between strains for each variety is advanced to explain these findings, and its relation to the selection of seed tubers is discussed.

I. Introduction.

During the last few years, some thousands of tubers and plants of the commoner Australian varieties of potato have been tested for the presence of virus X. In any single variety, the majority of tubers and the plants grown from them carry mixtures of strains which exist in various proportions; but most of the mixtures vary in severity within a comparatively small range. There are generally a few tubers or a few plants in any lot of 100 or more carrying mixtures that are either definitely milder or more severe than the average. By selection within the variety Up-to-date, tubers carrying a range of mixtures were sorted out, and an inverse relation was found between the severity of the mixture of virus X carried in a plant and the yield of tubers (1).

A reduction in loss of yield from infection with virus X is possible by selecting families or tuber lines carrying the mildest strains. Immediately the question arises: if a family contains a mixture of virus X consisting predominantly of the mildest strains, and is multiplied through a number of vegetative generations, will the average severity of the mixture remain constant, or will the severe strains gradually increase in concentration? Is there a natural equilibrium between strains for a particular variety? Answers to these questions are probably linked, and are of importance to agricultural workers interested in the maintenance of quality seed-stocks.

* An officer of the Division of Plant Industry.

An investigation of the average severity of strain mixtures was begun, using three varieties of potato: Carman, Western Australian Delaware, and Tasmanian Brownell.* There were two strains of Carman, one early and the other late. Carman was originally an early variety, but in most crops of Early Carman, however carefully rogued and selected, there are generally a few late maturing types. By selection from amongst these the late strains were founded, and came into cultivation in Victoria during the early part of this century. Commercial crops of Late and Early Carmans have a common vegetative origin, but have remained distinct for 25 or 30 years. The Early and Late Carmans used in these experiments were certified stocks grown in widely separated districts of Victoria, one in Gippsland and the other in Beech Forest.

There were two stocks of Delaware, both from Western Australia. One was from a farmer's stock of certified seed, the other was multiplied from material selected by officers of the Department of Agriculture from certified stocks.

The Brownell stock was descended from the original lot of this variety imported into Tasmania from New South Wales, and it had been grown at Woolnorth in north-western Tasmania for over 25 years. It included a range of ill-defined types such as appear in any variety of potato grown for so long without careful selection. It was relatively free from aphis-borne virus diseases.

2. Method of Inoculation.

In this series of experiments, inoculations were made from about 1,500 tubers of the three potato varieties to *Datura stramonium*. The inoculations were performed by a method designed to eliminate the more time-consuming operations of the usual technique. The tuber itself was used for inoculation. In trials with this method, over 90 per cent. of the tubers produced infection, which was sufficient for the purpose of the investigation. In practice, it was effective when the tubers were fully turgid, but as they aged and lost water the percentage of infection fell off. Various modifications of technique were introduced, and finally the method was made effective with quite shrivelled tubers. The procedure eventually adopted was as follows:—

The tubers were numbered, and set out in order on a tray. Six-inch pots, each containing two or three *Datura* seedlings, of which the first true leaves were expanding, were set out on the bench with the necessary identification written on a wooden peg label. At hand were stacks of coarse sandpaper cut in 1½-inch squares, and pieces of plain paper about 6 inches square; also a dropping burette containing dilute phosphate buffer, about M/200 at pH 7. A piece of sandpaper was placed on a piece of paper, the label was lifted from the pot containing the plants to be inoculated, and used to hold paper and sandpaper firm. On a corner of a tuber the skin was broken and adhering dirt removed by drawing it once heavily over the paper; and the exposed surface was lacerated by rubbing it on the sandpaper. The paper and sandpaper were used only once. One to several drops of the buffer

* These are local names for varieties of which the correct names are Carman No. 1 and (probably) Earliest of All and Adirondack.

solution were made to fall on the exposed surface of the tuber, which was then drawn across the leaves of the two or three *Datura* seedlings in one pot, the pot label being used as a support. The leaves had previously been dusted with fine carborundum powder. The inoculated leaves were sprayed with water from a wash bottle, and the pot returned to its place.

The use of the buffer solution and washing the leaves after inoculation were particularly necessary when the tubers were at all shrivelled. This procedure gave 100 per cent. infection with fully turgid tubers on young fast-growing plants, and if the tubers and plants were both in poor condition, about 90 per cent. of the tubers infected at least one of the three plants inoculated.

The effect of loss of turgidity in the tubers and improved technique is shown in the following graph of inoculations with Early and Late Carman tubers over the period when the final method was being developed (Fig. 1). The Early Carmans sprouted in the bag, in which they were kept for lack of storage space, and lost their turgidity; the Late Carmans remained firmer, as they sprouted later and more slowly. When the Early Carmans began to shrivel, the percentage of misses increased, but successive modifications of the inoculation technique gradually brought the number of misses down to the same level as for the Late Carman tubers.

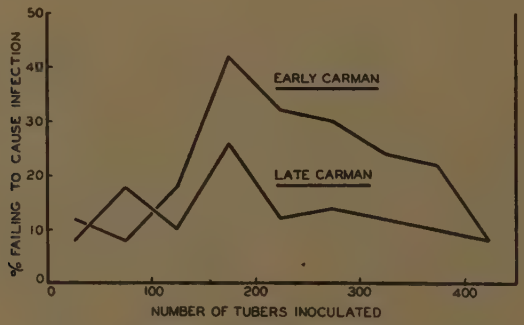

FIG. 1.—Illustrating the fall in efficiency of inoculation direct from ageing tubers by the method originally adopted (Tubers 1–200) and the recovery of efficiency, even when shrivelled tubers were used, by gradual improvements in the technique of inoculation (Tubers 201–400). The Early Carman tubers sprouted and lost their turgidity earlier than the Late Carman tubers. The period between the first and last inoculations was three months.

When symptoms were fully developed on infected *Datura* plants they were rated. Plants without symptoms were inoculated with a necrotic strain of virus X to see if they carried a masked strain or were free from infection.

The plants were rated according to the mottle and the degree of necrosis produced. Mottles were rated: 1, infection without symptoms or faint mottle; 2, medium mottle; 3, bright mottle; if the leaves were slightly rugose they were rated 1 or 2 according to the degree of rugosity; and degrees of necrosis were rated: 1, slight superficial necrosis; 2, severer superficial necrosis; and 3, necrosis through the thickness of the lamina killing sections of the leaf. The ratings were added and the mean total rating for infected plants was taken as the index of severity. Tubers failing to produce infection were left out of consideration in comparisons of severity.

When comparisons were being made between varieties or families of tubers, the treatments were replicated and randomized so that the results were comparable and could be treated statistically. Different lots of test plants and experiments performed at different times produced higher or lower average ratings, but this did not invalidate comparisons made at the same time on comparable plants. The question of rating for severity has been dealt with at length elsewhere (1).

3. Severity of Mixtures Carried in Carman Potatoes.

The first experiment, in which inoculations were made from the Early and Late Carmans, gave results which were consistently repeated in every other experiment involving a comparison of these two lots of material. The results of the severity ratings are shown in Table 1.

Table 1.—Frequency Distribution of Mean Ratings for Severity of Strain Mixtures of Virus X Carried in Early and Late Carman Potatoes.

Variety.	Frequency of Ratings.						Mean Rating.
	0·0.*	0·1–1·0.	1·1–2·0.	2·1–3·0.	3·1–4·0.	4·1–5·0.	
Early Carman ..	12	6	20	52	12	2	2·68
Late Carman ..	11	3	26	53	11	0	2·64

* No infection.

The distributions of frequency ratings are obviously similar, and the mean ratings are very close. There can be no doubt that the mixtures of virus X carried in the Early and Late Carman were almost identical.

4. Severity of Mixtures in Five Lots of Three Varieties.

There were four experiments in which direct comparison was made between the Early and Late Carman, the two lots of Delaware, and the stock of Brownells. The general level of severity ratings varied considerably between experiments because of the varying environment in the greenhouse, but the results of the four experiments were consistent. The mean ratings obtained by pooling the data of the four experiments are shown in Table 2.

Table 2.—Mean Ratings for Severity of Strain Mixtures of Virus X Carried in Five Lots of Three Varieties of Potato. Data from Four Experiments.

Delaware.		Carman.		Brownell.
Selected Stock.	Certified Stock.	Early.	Late.	
2·11	2·32	2·57	2·68	3·19

The three varieties carry mixtures of virus X differing considerably in severity. The ratings for Early and Late Carman are not significantly different, but the ratings for the two lots of Delaware are. The selected stock of Delawares was derived from a certified stock of Delaware similar to that used in these experiments; single plant selections were made by officers of the Western Australian Department of Agriculture on a basis of vigour and relative freedom from the slight mottle produced in this variety by virus X. Such methods of selection with the variety Up-to-date have been shown (1) to reduce the proportion of plants carrying the severer strain mixtures of virus X. That a similar result was obtained in this variety is suggested by the frequency distribution of ratings in Table 3. These summarize the data for Delaware from two of the four experiments mentioned above. Other experiments, although the general levels of rating were often different, gave similar results.

Table 3.—Frequency Distribution of Mean Ratings for Two Lots of Delaware. These Represent All Tubers Producing Infection in Two Experiments.

Stock.	Frequency of Ratings.			
	0·1–1·0.	1·1–2·0.	2·1–3·0.	3·1–4·0.
Selected	11	15	16	0
Certified	12	18	17	7

5. Discussion.

This work shows how similar was the population of mixtures of virus X carried in different lots of the same variety of potato. There were also wide differences between varieties. One explanation of these findings would be that the original stocks of each variety became infected at one source, and that the mixtures of strains have remained constant in the vegetative descendants of the infected plants. However, there are difficulties in this hypothesis. Families of potatoes containing mild mixtures produce higher yields than plants containing severe mixtures; and if the mixtures remain constant the former would multiply at a faster rate and displace the others. The incidence of the severer strains of virus X would be reduced, and the severest might be eliminated. In fact, the mildest mixtures occur only in small

proportions amongst populations of all the four varieties that have been tested on a large scale (Up-to-date or Factor and the three described in this paper); and severe strains are present in the majority of mixtures.

It has been found on many occasions that mixtures containing predominantly mild strains with a small admixture of the ringspot and necrotic strains do not remain constant when sub-cultured a number of times on susceptible hosts (2). The severer strains often multiply at the expense of the milder strains, and the average severity of the mixtures increases. This was noted by Kenneth Smith (4) in early experiments with virus X. The explanation of such results appears to be that an attribute of severe strains is their ability to multiply more quickly than milder strains and reach a higher concentration in their host plants. This facility in multiplication partly accounts for the severe reaction of host tissues.

In extreme instances a limit to the multiplication of a severe strain is automatically imposed by the damage it does to the tissues of its host. An example is the necrotic strain of virus X. In varieties of potato on which it causes a fully necrotic reaction it cannot or it can barely persist in the pure state because it kills the sites for its own multiplication. It can persist in mixtures with milder strains when the mixtures containing it produce a mottle or only partial necrosis. Extending this principle, the limit set to virus multiplication is inversely related to the injury done to the host tissues. At the other extreme, mild strains may never reach this limit, because they cannot multiply fast enough or to a high enough concentration. A mixture of mild and severe strains in a susceptible host will generally approach an equilibrium represented by the balance of two opposing tendencies. A hypothesis of this kind offers a feasible explanation for the occurrence of similar populations of virus mixtures in long-separated families of the same potato variety. As different varieties react differently to strains of virus X, it is logical that they should carry the various strains in different proportions, and that the average severity of strain mixtures should be correspondingly affected.

The control exerted on the multiplication of the severer strains in some varieties of potato cannot however be the destruction or injury of tissues, as quite severe mixtures may have no effect on the top growth of the infected potato plants (1). The effect on yield is probably the controlling influence which limits the multiplication of severe strains. At the other end of the scale, the partial segregation of mild strains in some tuber lines or families, which thus become higher yielding, would be counter-balanced by the gradual emergence of severe strains, at first present in traces.

This hypothesis can be adequately tested only by experiments extending over a period of years. In the meantime it is worth the consideration of agricultural workers whose function it is to maintain the best quality seed stocks. Salaman (3) has suggested that a way of reducing losses from virus X in susceptible varieties is to found and maintain stocks carrying a masked strain. Recent work at Canberra (unpublished) suggests that the masked strain may not give complete protection against severe strains of virus X, and proof has been obtained that it can cause a 12 per cent. loss in yield. Hence

the loss from even so mild an infection as this and the chance that infiltration of severer strains might occur in spite of it must be balanced against the ease and cheapness of this method of controlling greater losses. Sometimes stocks that contain a masked or mild strain contaminated with small concentrations of the severer strains may be the best available. Then it may be necessary to make regular periodical selections from the parent stock to prevent a general drift towards higher concentrations of severe strains and lower yields.

In any case, such a practice is advisable because of the well-known heterogeneity of many potato varieties. The heterogeneity due to infection with virus X is imposed on this other form of heterogeneity (1) which appears from a recent discussion (5) to be fundamental to vegetative propagation. Careful selection should act equally on both, and result in an improvement of many established potato varieties. This has been the general experience in Australia where such work has been undertaken, particularly in Tasmania where the Department of Agriculture has for a number of years maintained improved stocks of several varieties.

6. Acknowledgments.

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Fertilizer Trials in Southern New South Wales Pine Plantations.

*By W. V. Ludbrook, B.Agr.Sc., Ph.D.**

Summary.

1. *Pinus caribea* and *P. taeda* affected by fused needle disease did not respond to soil treatment with phosphatic fertilizers during the first season after treatment, but the percentage of recovery from needle fusion became much higher in treated than in untreated trees during the subsequent three seasons.

2. Soil treatment with boron compounds produced a much quicker response than superphosphate in diminution of needle fusion symptoms, many of the treated trees producing new growth free of fused needles the first season after treatment. This effect usually lasted only one season, however, and boron treatments subsequently proved useless or detrimental.

3. During the second and third seasons after broadcasting phosphatic fertilizers under the trees, marked responses in volume increment and in recovery from needle fusion were shown by *P. caribea* and *P. taeda* at Woodburn plantation. The difference between the growth rates of treated and untreated trees was greater during the third season after treatment than during the second.

4. Treatment of *P. taeda* at Broadwater plantation with 2½ cwt. of superphosphate per acre was ineffective, possibly because of drought.

5. In the Moss Vale district, 1½ or 3 cwt. of superphosphate per acre had little or no effect on *P. radiata* 7, 9, or 17 years of age, during three seasons after application. The same treatments produced a 35 per cent. increase in height growth, as compared with controls, in one year old self-sown seedlings on a burnt area at Penrose, during the first season after application. This was maintained during the next season in the plots treated with 3 cwt. of superphosphate, but not in those treated with 1½ cwt.

1. Introduction.

The work here reported began as part of an investigation of the disease of *Pinus* species termed needle fusion or fused needle. This has been described in previous publications (2, 3, 4, 5). It is a physiological disorder common on infertile sandy soils of very low phosphate content. Soil treatments of diseased *P. radiata* and *P. muricata* with various fertilizers and chemicals were begun by the writer at Penrose plantation (New South Wales) in 1934, but the response of these species to treatment was slow, and the plantation was destroyed by fire before reliable results were obtained. From the results available, superphosphate and boron compounds were selected for further trial, and experiments with individual diseased trees of *P. caribea* and *P. taeda* at Woodburn and Broadwater plantations, begun in 1938, gave the results summarized in Table 1.

These results were confirmed and extended by those of larger experiments subsequently begun at five plantations, in which replicated plots received broadcast dressings of superphosphate, rock phosphate, or boron compounds. The work has now reached a stage at which definite conclusions can be drawn as to the effect of these compounds

* Plant Pathologist, Division of Plant Industry.

on needle fusion, and also (in some experiments) as to the beneficial effect of phosphates on growth-rate (Table 2). In other experiments, it is still uncertain whether any response to phosphates will occur. It is hoped to keep all the experiments under observation until reliable data on the extent and persistence of response to phosphatic fertilizers have accumulated, but as this will take several more years, it is thought advisable to publish the four years' results already obtained.

Young (5) is inclined to extend the term "fused needle disease" to include several other types of unhealthy growth, such as short or yellow needles, or lack of foliage in the crowns. In this paper it is restricted to trees showing definite "fusion" of the needles, which Neilson-Jones (2) and the writer consider probably indicates a condition distinct from general malnutrition, although responsive to similar treatment. However, from the practical viewpoint, the latter condition is much the more important, and the subject of the present investigation has changed from needle fusion as such, to the effect of phosphatic fertilizers on the growth-rate of all treated trees, whether affected with needle fusion or not.

Except where otherwise stated, the experiments mentioned in this paper were on soils of very low fertility, derived from Hawkesbury sandstone or similar formations. The soils consisted mostly of grey or yellowish-brown sandy loams, of pH ranging from 4·8 to 6·5, with subsoils of decomposing sandstone or sand containing ironstone gravel and small amounts of yellow clay.

2. Treatments of Individual Diseased Trees.

In the plantations visited by the writer, the percentage of trees showing definite needle fusion symptoms was low. As the primary object of these experiments was to determine the effects of the treatments on disease symptoms, the fertilizers were at first applied to individual diseased trees, or small groups where available, as a much greater number of diseased trees could be treated in this way in a given time than by broadcasting each of the compounds tested over separate large areas, each containing a very few diseased trees. Moreover, it was at first thought that concentrated dressings of superphosphate might be more effective than broadcast dressings, as was found with young pines on coastal sands in Western Australia (1). Subsequent experience has shown that under the conditions of the writer's experiments, broadcast dressings are more effective.

In early spring, amounts ranging from $\frac{1}{2}$ lb. to 6 lb. of superphosphate, and $\frac{1}{4}$ to 2 lb. of borax or calcium borate per tree, separately or mixed, were scattered on the surface of the soil within 6 to 12 feet of the diseased trees, which were mostly 8 to 10 years old and 6 to 15 feet high at the time of treatment, as no suitable younger diseased trees were available. The treated trees and controls were examined each winter during the four years after treatment, and any increase or diminution in the severity of disease symptoms was noted. As an indication of growth-rate, the trunk diameter was measured at the same point each season. Owing to the varying deformities caused by the disease, it was not practicable to make all these measurements at breast-height, or at any other uniform height for all trees.

It is evident from Table 1 that boron compounds gave the quickest response in diminution of needle fusion symptoms, superphosphate having no effect the first season after application. This response proved to be only temporary, however, and although the latest observations show an apparently higher percentage of recovery from needle fusion in the trees treated with superphosphate plus boron compounds than with superphosphate alone, this is of doubtful significance, and has not been confirmed in subsequent experiments on a larger scale, in which boron compounds had a detrimental effect. Most of the diseased trees which made healthy growth the first season after treatment with boron compounds reverted to diseased growth later, although severely diseased twigs of this reverted new growth were shown by spectrographic analysis to contain abnormally high percentages of boron.

TABLE 1.—RESPONSES OF INDIVIDUAL DISEASED TREES OF *Pinus taeda* AND *P. caribea* TREATED IN 1938 WITH SUPERPHOSPHATE AND BORON COMPOUNDS.

Treatment.	Total Number Treated.	Average Trunk Diameter in July, 1940 (Inches).	Increase in Trunk Diameter, July, 1940, to July, 1942, as Percentage of Diameter in July, 1940.	Percentage of Treated Trees Recovering from Needle Fusion.					
				First Season after Treatment.			1938–1942.		
				Complete Recovery	Partial Recovery	No Recovery	Complete Recovery	Partial Recovery	No Recovery
			%	%	%	%	%	%	%
Control	95	3·6	9·2	3	40	57	25	20	55
Superphosphate ..	23	3·4	19·9	0	52	48	52	22	26
Superphosphate plus borax or calcium borate	37	3·6	14·8	17	83	0	68	13	19
Borax or calcium borate	42	3·2	7·9	36	54	10	5	24	71

Although superphosphate had little or no visible effect the first season after application, there was a gradual recovery from needle fusion, improvement in colour and density of foliage, and increase in growth-rate during the next three seasons in the majority of treated trees, and large-scale experiments gave ample confirmation of its beneficial effects. Possible reasons for the lack of response in the remainder will be discussed later.

3. Broadcast Treatments of Replicated Plots.

(*a*) *Pinus caribea* and *P. taeda*.

As soon as responses to superphosphate and boron compounds were observed in individual trees, randomized block experiments were begun at Penrose in 1938, using newly planted *P. radiata* in one and *P. radiata* four years old in another, treated with these compounds. They were destroyed by fire in 1939. Further experiments were begun at four

other plantations in 1939, but as no younger trees were available, they had to be confined to established stands from 7 to 17 years old. Positive responses to phosphatic fertilizers occurred in some of these experiments during 1941 and 1942.

The most marked responses took place in *P. caribea* and *P. taeda* on an acid, infertile grey sandy loam at Woodburn plantation, on the coast 160 miles south of Sydney (Table 2). These trees were 9 years old at the time of treatment. In *P. caribea,* the fertilizers were broadcast over plots 90 feet square; untreated buffer areas 20 feet wide were left between adjacent plots, and tree measurements were confined to an area about 60 feet square in the middle of each treated area, so that most of the roots of each measured tree would be within the treated area. About 40 trees were measured in each plot. In *P. taeda,* the treated areas were 80 feet square, and about 30 trees were measured in each plot, on an area about 50 by 55 feet. The superphosphate used contained 22 per cent. of total P_2O_5 (20·5 per cent. being water-soluble) and the finely ground rock phosphate contained 37 per cent. of P_2O_5, none of which was water-soluble.

The trunk diameter over bark at breast height (D.B.H.) of every tree in the measured plots was recorded annually in midwinter. The height, diameter, and bark-thickness at several points on the trunk were also recorded for three representative trees in each plot, and graphs were constructed for each species, by means of which the volume increment could be estimated from the D.B.H. measurements.

There was no obvious effect in either experiment during the first season after treatment, but during the second and third seasons there was a marked increase in the relative growth-rate of the trees receiving phosphatic fertilizers (Table 2). In December, 1940, all the trees in both experiments were partly defoliated by a severe hailstorm of 30 minutes' duration, which probably reduced the leaf area of both species by at least 50 per cent. This decreased the rate of volume increment by roughly a half, as compared with the previous two seasons. *P. taeda* was worse affected than *P. caribea,* which has coarser needles and is more resistant to hail. The foliage destroyed by the hail was replaced faster in the fertilized than in the unfertilized plots, and the relative increase in growth rate due to fertilizer was more marked during the third season after treatment than during the second. The rate of recovery from needle fusion was faster in the fertilized plots than in the controls (Table 2).

Young (5, p. 69) states that the cost of applying 3 cwt. of superphosphate per acre to Queensland pine plantations averaged 16s. per acre. During the second and third seasons after the application of 3 cwt. of superphosphate per acre, *P. taeda* at Woodburn increased in volume of timber at the estimated rate of about 145 cubic feet of timber per acre per annum (Table 2), while the corresponding figure for the controls was 82. The difference, viz., 63 cubic feet, or 756 super. feet per acre per annum, was the extra increment presumably due to the fertilizer treatment. Taking the minimum stumpage value of this timber (i.e., its value as standing timber, ignoring costs of felling and marketing) as 1s. per 100 super feet (a conservative figure) it is evident that the value of the two seasons' extra volume increment due to fertilizer was almost sufficient to repay the cost of application, apart from any further extra increment that may occur.

TABLE 2.—EFFECTS OF BROADCAST FERTILIZER TREATMENTS ON GROWTH (AS MEASURED BY ESTIMATED INCREASE IN VOLUME OF TIMBER) AND ON NEEDLE FUSION SYMPTOMS IN *Pinus caribea* AND *P. taeda* AT WOODBURN. TREATMENTS APPLIED IN JULY, 1939.

Species.	Number of Replications.	Treatment (per acre).	Estimated Increase in Volume of Timber between July, 1940, and July, 1942. (1) Expressed as Mean Absolute Increase in Cubic Feet per annum.*		(2) Expressed as Percentage Increement per Annum of the Mean Tree Volume for the Above Periods.	Initial Total Number of Diseased Trees.	Percentages of Initial Total Number of Diseased Trees. (1) Now Free of Needle Fusion Symptoms.	(2) Still showing Needle Fusion Symptoms but Recovering.	(3) Needle Fusion Symptoms Unabated or Worse.
			per tree.	per acre.	%		%	%	%
Pinus caribea	6	None ..	·158	75	13·7	49	54	4	42
		2 cwt. superphosphate	·223	105	18·6	33	91	9	0
		2½ cwt. ground rock phosphate	·242	114	19·9	31	78	15	7
Pinus taeda	4	None ..	·165	82	9·4	23	68	18	14
		1½ cwt. superphosphate	·264	124	15·5	25	92	0	8
		3 cwt. superphosphate	·309	145	18·1	25	100	0	0

* The differences in volume increment between treated and untreated trees are significant at the 1 per cent. level in *P. caribea*, and at the 5 per cent. level in *P. taeda*. The difference between the two fertilizer treatments is not significant in either species.

This, of course, ignores losses in trimming and milling, and involves the incorrect assumption that all the additional timber would be marketable. In view of the incompleteness of the data, and the abnormal nature of the climate during the two seasons mentioned (see Discussion), it is obvious that much more time must elapse before a reliable estimate of the economic soundness of the fertilizer treatment is possible. However, from the figures cited, it appears reasonably likely that the application of phosphatic fertilizer will be profitable under the conditions of the writer's experiments at Woodburn.

Additional experiments were subsequently begun with *P. caribea* to test the effects of ¾ and 1 cwt. of superphosphate, and dressings of rock phosphate containing equivalent amounts of P_2O_5. The latter experiments, which include areas of good, average, and very poor growth, have not yet been established long enough to yield results.

At Broadwater plantation, on the coast 170 miles south of Woodburn, treatment of *P. taeda* with superphosphate was much less effective. Trees 11 years old, to which 2½ cwt. of superphosphate per acre was

applied in 1939, had not shown any significant increase in growth-rate or improvement in general appearance by 1942, and the percentage of trees recovering from needle fusion was much lower than at Woodburn. Possibly adverse climatic conditions prevented a response to fertilizer here (see Discussion).

(*b*) *P. radiata.*

In 1939, two experiments were begund in *P. radiata* 7 and 17 years old on reddish sandy loam at Wingello, and one on a shale soil at Belanglo, in *P. radiata* 9 years old. Both these plantations are in the Moss Vale district. Dressings of 1½ and 3 cwt. of superphosphate per acre caused no statistically significant response in growth or consistent recovery from needle fusion in any of these experiments, except for a barely significant response in the 1941-42 season's growth of the 17 year old *P. radiata* at Wingello, and for slight indications of greater development of mycorrhizal fungi, as evidenced by larger and more numerous *Boletus* sporophores, in the treated plots at Belanglo in 1942. Both in this experiment and in the 7 year old *P. radiata* at Wingello, the average diameter increments were slightly greater in the treated plots than in the controls during 1941 and 1942, but the differences were not significant.

Dressings of 1½ and 3 cwt. of superphosphate produced a highly significant response in the height-growth of one year old self-sown *P. radiata* on a Hawkesbury sandstone soil at Penrose, also in the Moss Vale district, during the first season after treatment. The average height-increment was over 35 per cent. greater for both series of treated plots than for the controls, though there was not obvious difference in colour or density of foliage. This difference was maintained during the 1941-42 season by the 3 cwt. plots, but the 1½ cwt. plots grew no faster than the controls. In an additional experiment begun in 1941, dressings of ¾ cwt. of superphosphate, and of ground rock phosphate containing an equivalent amount of P_2O_5, produced no response in 1942.

4. Discussion.

On the whole, the response to phosphatic fertilizers in the writer's experiments has not been as consistent or as marked as in those of Young with *P. caribea* and *P. taeda* on similar soils in Queensland (5). The lack of response by *P. radiata* may be due to the fact that this species has a relatively high minimum P_2O_5 requirement for satisfactory growth. According to Kessell and Stoate (1), a P_2O_5 content of 400 parts per million is necessary in the surface and sub-surface soils of Western Australian plantations, though 300 p.p.m. may suffice if maintained for a depth of 2 to 3 feet. In their experience the growth of *P. radiata* is very unsatisfactory, and responses to treatment are only transitory, on soils containing less than 150 p.p.m. of P_2O_5.

The P_2O_5 content of the soils on which the writer's plots of *P. radiata* are situated has not been fully investigated, and appears to be rather variable. The mean value of the few determinations made is 150 p.p.m. in the A horizon, which varied from 6 to 10 inches in depth. It would require very much heavier dressings than those applied hitherto to bring this up to 400 p.p.m. The quick, but possibly

transient, response to superphosphate by *P. radiata* seedlings at Penrose indicates that the reaction of seedlings to this fertilizer differs from that of the older trees in other experiments.

Young (5, p. 69) considers that in Queensland, 110 and 150 p.p.m. of P_2O_5 in the top 4 inches of soil are the minima for satisfactory growth in *P. caribea* and *P. taeda* respectively. The soils carrying these species in the writer's experiments contained amounts of total P_2O_5 ranging from 80 to 110 p.p.m., and the dressings of phosphatic fertilizers applied were sufficient to raise their P_2O_5 status well above Young's minimal values. As this author has remarked, the failure of many of the individually-treated trees to respond may be explained by the fact that the treatment probably did not include the outer portion of their root-area; however, this does not apply to the broadcast-treated plots at Broadwater, where it is thought that climatic factors may have been concerned.

In each of the writer's experimental areas, the rainfall has been abnormally low since the experiments were begun. Thus at Woodburn, the rainfall for the period from July, 1940, to July, 1942, i.e., that covered by the growth-measurements in Table 2, was 27·2 inches per annum, or 43 per cent. below the mean of 47·5 inches per annum; at Broadwater it was 18·5 inches per annum, or 41 per cent. below the mean of 31·6 inches per annum. Although the percentage deficiency from the mean was less here than at Woodburn, the actual rainfall was much lower; only 13·8 inches fell from July, 1941, to June, 1942, inclusive.

It is thought unlikely that a reliable estimate of the effect of phosphatic fertilizers would be possible under these conditions. Although there has been a considerable accumulation of dry needles under the trees on the experimental areas, there is very little evidence of humus-formation at the soil surface, the hastening of which Young (5) considers to be an important factor in the beneficial action of phosphatic fertilizers, and which has apparently been largely inhibited by drought conditions. The rainfall has also been abnormally low in the Moss Vale district, but the relative importance of drought and the greater P_2O_5 requirement of *P. radiata* in causing the lack of response by this species to phosphatic fertilizers is not yet known.

While it is evident that under certain conditions a marked stimulus to growth may result from the use of phosphatic fertilizers in New South Wales plantations, the economic value of the treatment must remain uncertain until it has been shown that its beneficial effects last long enough to make it profitable, and the experimental areas have received adequate rainfall for a sufficient time to indicate the effect of phosphatic fertilizers under normal moisture conditions.

5. Acknowledgments.

Thanks are due to the New South Wales Forestry Commission for assistance with the field work, to Mr. H. R. Gray (of the Commonwealth Forestry Bureau) for information on his unpublished method of estimating the volume of timber in standing trees, and to Mr. G. A. McIntyre (Assistant Biometrician of the Council) for the statistical examination of the data and the construction of diameter-volume graphs.

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The Control of *Pediculoides ventricosus* (Newport) in Insect Cultures.

By F. J. Gay, B.Sc., D.I.C., and T. Greaves.**

Summary.

Pediculoides ventricosus (Newport) is frequently a troublesome pest in stock cultures of insects. A method is described for controlling this mite by the use of a 2 per cent. solution of dinitro-ortho-cyclohexylphenol in oil.

Entomological literature contains frequent references to the trouble experienced in maintaining stock cultures of insects affecting stored products owing to the invasion of the cultures by the mite *Pediculoides ventricosus* (Newport). This mite is normally ectoparasitic on the larvae and to a lesser degree on the pupae and adults of a number of insects, particularly those affecting stored products. The obvious effects on an infested culture are a greatly reduced yield of experimental material and a lowered vitality of this material. (In our cultures heavy infestations of mites at times reduced the yield by more than 50 per cent.). In addition, persons handling infested cultures are liable to develop a rash which is accompanied by severe itching. A comprehensive account of the irritation which *P. ventricosus* produces on human skin has been given by Swan (1934). During the past two years, research on problems concerning insects attacking stored wheat has made it necessary to maintain stock cultures of the more important grain pests. The presence of *P. ventricosus* in these cultures was first noticed about two months after the rearing of laboratory stocks was begun in June, 1940. They were found in the stocks of *Calandra oryzae* and to a lesser extent in those of *C. granaria*. These insects were reared in quart-sized glass jars fitted with metal screw-top lids, aeration taking place through a hole in the lid, 1½ inches in diameter and covered with 60-mesh metal gauze.

A brief description of the method used in breeding stocks of *Calandra* spp. is necessary to explain the control measures which were tried. Every week eight culture jars are installed for each of the two species. In each jar are placed 400 g. of wheat and approximately 100 adults. The adults are allowed to oviposit for two weeks, when they are removed and the wheat is then incubated at 78°F. and 60 per cent. R.H. for a further period of six weeks. The progeny begin to emerge during the fifth week after installation (three weeks after the removal of adults), maximum emergence occurs during the sixth and seventh weeks, and a reduced number are obtained in the eighth week, after which the cultures are discarded. The emerging adults, which are sieved off weekly, are kept for experimental purposes in two age groups, viz., up to one week old, and one to two weeks old. When they are two weeks old all adults not required for use in setting up of new cultures are destroyed.

The first attempt at controlling the infestation was based on the assumption that since the wheat used for the cultures was clean and free from mites, they were being introduced on the bodies of the adult

* An officer of the Division of Economic Entomology.

weevils used for breeding. Accordingly, before being placed in the cultures, the breeding weevils were dusted with sulphur, which has been widely used as an acaricide. This dust treatment had no deleterious effects on the weevils, neither did it have any appreciable effect on the mite population. Thereupon, the sulphur dust was applied to the wheat used in the cultures as well as to the breeding weevils. It was found, however, that the weevils were adversely affected by this intensive dust treatment without any accompanying diminution in the numbers of mites.

These failures led to a more detailed study of the distribution of the infestation. It was found that young mites were migrating in enormous numbers from two particular batches of jars, the seven and eight weeks old cultures of *C. oryzae,* and were infesting all other jars in the culture room. This localization of the source of infestation appeared to be linked with the fact that, in *C. oryzae,* the fully-fed larvae commonly bore holes out to the external surface of the grains and push out the accumulated floury frass prior to pupation. These holes would allow the mites to gain access to the weevil larvae, which previously had been completely protected from attack by their enclosure within the grains. At the temperature at which the *Calandra* stocks are maintained (78°F.), the fully-fed weevil larvae occur mainly in the five weeks old cultures, and mites infesting these cultures could, according to the data given by Swan, produce a new generation in approximately ten days. This new generation could then be expected to emerge from the seven and eight weeks old cultures, and this, as mentioned above, was what was happening.

Working on the assumption that the continuous reinfestation of the cultures was due to newly-hatched mites crawling from the seven and eight weeks old *C. oryzae* cultures, an attempt was made to control the mites by the use of chemically-treated bands. Cloth tape, half an inch in width, was soaked in a 6 per cent. solution of beta-naphthol in alcohol and then allowed to dry. Bands of this treated tape were fastened around every jar in the culture room. This treatment killed very large numbers of mites; in fact, the white bands on some jars assumed a distinct orange hue after two days owing to the enormous numbers of mites trapped and killed by the bands. However, the cultures were not freed of infestation for two reasons. Firstly, a certain number of mites were able to pass over the dead bodies of their fellows clustered on the bands and so to escape the contact effect of the beta-naphthol. Secondly, there was sufficient air movement at times to enable young mites to be air-borne from jar to jar.

Our attention was next drawn to the work of Page and Shafik (1936), who reported successful control of mites in insect and fungus cultures by means of fumigants which eliminated the mites without seriously affecting the insects or fungi. Of the materials they used, methyl salicylate appeared the most satisfactory from our point of view, since they showed that at concentrations which killed the mites, cultures of *Calandra granaria* were affected only slightly. The concentration selected for our test was 0·0025 ml. per litre (0·1314 lb. per 100 cu. ft.), and the dosages required were 0·004 ml. per individual culture jar and 54·5 ml. for the culture room. Each jar was treated by pipetting the dose on to filter paper inside the jar, while the dose for the room was applied by spraying evenly with a hand atomizer.

An exposure period of 24 hours was allowed for this fumigation. After a few days, mites were still in evidence, and the bulk of the jars were retreated with the same dosage of methyl salicylate. Subsequent examination showed that some of the mites had been killed, but the infestation was not reduced significantly.

At this time, current laboratory work on weevil control indicated the high contact efficiency of straight oil sprays containing additive toxic materials. An outstanding example was a solution of dinitro-ortho-cyclohexylphenol in oil, and it was decided to try this material for mite control.

The solubility of dinitro-ortho-cyclohexylphenol in oil depends on the type of oil used. From the figures given by Boyce *et al.* (1939), it was possible to select an oil which gave ready solubility. The grade chosen was G.194, supplied by the Shell Company, and it corresponded closely to the dormant type oil referred to by Boyce *et al.* as giving the highest solubility of the various petroleum spray oils investigated by them.

A 2 per cent. solution of dinitro-ortho-cyclohexylphenol in oil G.914 was prepared. Strips of cloth, soaked in this solution and then drained, were applied as bands to the culture jars. An inspection of these bands after one week revealed thousands of dead mites trapped by the oil film. This was followed in a few weeks by a noticeable diminution in the amount of skin irritation experienced by those handling the culture jars and by a gradual increase in the numbers of weevils emerging from the cultures. It was evident that a positive reduction of the infestation had been achieved. Within two months no sign of mites could be detected in any of the cultures. The method of application was then simplified to merely wiping the sides and lids of the jars with a cloth dipped in the oil solution, and this treatment has been continued as a routine precautionary measure against new infestation.

The treatment described above provides a convenient means of controlling *P. ventricosus* in insect cultures. Very little time is involved, and the culture jars are not difficult to handle. This latter point is of some importance, since in some laboratories, cross infestation by mites is guarded against by standing all culture jars in trays of oil.

Since the work described in this paper has been incidental to the research on grain pests, no attempt has been made to investigate the possibilities of other additive toxic materials. Two compounds which do merit consideration, however, are beta-naphthol, which showed a high degree of toxicity on the tape bands, and dinitro-ortho-cresol, which in tests against weevils showed a toxicity comparable to dinitro-ortho-cyclohexylphenol.

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Urena lobata—A Jute Substitute.

*By J. Calvert, D.Sc.**

Jute is almost exclusively an Indian product, so it is a matter of some moment in these days to be aware of possible local jute substitutes. Such a one is the fibre from a plant now growing naturally in Queensland, known botanically as *Urena lobata* and commonly as urena.

The plant and its fibre have been known for a considerable time and it has been used as a jute substitute in Brazil, Cuba, Madagascar, and other countries. In Brazil large quantities have been used for the manufacture of coffee bags (up to four million bags per annum) and in Madagascar production in 1926 reached over 1,000 tons. The Imperial Institute has reported favourably on a number of occasions on samples submitted, but the fact remains that under ordinary conditions it has not successfully competed with jute.

In a report presented to the Commonwealth Government in November, 1936, by Drs. Richardson and Dickson, reference was made to this plant as one from which fibre could be produced in Australia as it occurs naturally in Queensland.

Retting Trials.

When visiting the South Johnstone Research Station in May, 1940, the Chief of the Division of Plant Industry arranged with Mr. J. L. Schofield, Director of the Bureau of Tropical Agriculture, to have a parcel of half a cwt. of stems sent to Canberra for retting. These were retted under controlled temperature conditions. The fibre content calculated as a percentage of air-dry stems varied between 7·2 and 10 per cent. Samples of the fibre were favourably commented on by several merchants. Subsequently arrangements were made for half a ton of stems to be collected for retting and examination of fibre. The plants were growing wild, and as would be expected the stems varied in thickness and maturity. Nevertheless it was expected that spinnability could be determined from the fibre extracted.

Bundles of stems were packed in two large open crates. One contained 269 lb. of air-dry stems and the other 243 lb. The two crates were fixed in an upright position in flowing creek water (which had no visible movement) so that the basal portions of the stems were submerged to a little more than one-third the stem length. One crate remained upright for three and a half days and the other for five days. They were then placed horizontally and completely submerged with the root ends facing up-stream. The large variability in the thickness and the maturity of the stems obviated any possibility of determining a period of retting which would be an optimum for the whole material. It was necessary to keep a frequent check on the progress of the ret, and as different stems became completed they were removed and the fibre extracted. Approximately 50 lb. of fibre were obtained and forwarded in February to Ed. Bentley and Son, twine manufacturers,

* Research Officer, Division of Plant Industry.

Sydney. The following month Bentleys sent samples of card sliver, finisher drawing sliver, 4½ lea yarn, and 5-cord twist from this yarn, all manufactured from the *Urena*.

They also made the following comments:—

"*Handling.*—Very poor compared with jute. This is understandable, but greater care in the handling of future lots is most desirable.

Fibre.—There was a big variation in strength, probably due to excessive retting of certain parts. This you anticipated. These weak parts had an adverse effect on spinning quality.

Comparison with Jute, &c.—The sample we received compares only with a low-grade jute, both as to quality and colour. The writer has seen *Urena* fibre of very much higher quality and clearer colour.

General.—On the whole, we consider the experiment very successful, and think you should feel encouraged to make further trials, perhaps even to the extent of cultivating the plant. It is specially cultivated in Africa."

Although the Australian *Urena* fibre was obtained from such variable material and was comparable to a low-grade jute, yet the twine had a relative strength of 1058 as compared with Indian jute 1028 and Belgian Congo *Urena* 829. The coefficients of variability were 23·34, 38·65, and 29·70 respectively. These strengths and variabilities were not significantly different from one another.

Yields.

There are no Australian figures for the yield of plant material, or the yield of fibre, which may be obtained from an acre of land. In Cuba the plant is cultivated and yields of fibre exceeding one ton to the acre may be obtained annually. In most countries where the plant is found growing wild, it occurs in patches, and in assessing the yield per acre there is a tendency to sample the best areas.

In Madagascar 100 kg. of green stems are claimed to yield 7 kg. of dry fibre. Estimations from Trinidad suggest a yield of 20,000 lb. to 25,000 lb. of green stems per acre. This means a uniform stand, 7 feet high, and with a fibre content of 5 per cent. a yield of 1,000 lb. or more of fibre could be expected per acre.

Experimental plots in the Belgian Congo gave yields of dry fibre which varied from 1,336 to 1,781 lb. per acre.

Preparation of the Fibre.

The preparation of the fibre can be subdivided into four distinct operations—desiccation of the fresh stems, retting these stems, washing the fibre from the wood and freeing it from the soft slimy cortical tissue, and lastly drying the fibre.

Desiccation.

The stems should be cut at the flowering stage close to the root end. If they are harvested earlier they ret more easily and the fibre is fine and white. The fibre content, however, is too low. If the cutting is postponed until well after flowering the retting is rendered more

difficult. Also the burry seeds are included in the following processes and become entangled in the fibre, causing further trouble. The stems, after cutting, are tied into bundles of convenient size and left in the sun to dry until the leaves fall off. It is claimed by some French workers that if the drying is sufficiently rapid the adherence of the bark to the wood is weakened, but if the drying is too rapid there is likely to be a deterioration of the fibres.

Retting.

When the bundles of stems have dried sufficiently it may be preferable to remove the secondary branches before placing the stems in water. It is not possible to give a standard time-table of events in the retting of *Urena,* because the rate of the fermentation varies with the maturity and thickness of the plant material as well as with the temperature and the chemical constituents of the retting water.

It is best to utilize clear slow-flowing water, and if the temperature is approximately 68°F. the retting takes upwards of three to four weeks. The top thin end of the stem rets more rapidly than the older thick basal end, and the essential thing is to complete the ret so that the root end is not underdone nor the upper part overdone. The bundles are usually placed upright with approximately two-thirds of the stem out of the water. They remain so for two to five days, depending on the thickness and maturity of the material, before being placed horizontal and completely submerged. The fermentation of the tissues is then allowed to proceed to the stage where the outer layers of the bark are disintegrating and the fibrous portion from base to tip is fairly easily removed from the woody centre by hitting the surface of the water with the plant stems.

Washing.

Following the retting process, and while still wet, the woody cores of the stems are easily pulled out of the sleeves of fibre. Handfuls of filasse are then plunged into water and any foreign matter rubbed off. This fibre is then placed in a bath of slightly acid water where it turns a nice cream colour. The operator should at all times be careful not to allow the fibre to become tangled. It is obvious that this almost individual treatment of stems will make the fibre expensive, and this can only be minimized if some method of mechanical decortication of the retted stems can be devised. In this event the bundles of stems could be dried after retting and then passed to the decorticator. Fibre obtained by the dry method is not so clean as that obtained by the wet method.

Conclusion.

It is evident that fibre of a useful kind which may be used as a substitute for jute can be obtained from *Urena lobata* growing in Queensland coastal areas.

NOTES.

A Cheap and Rapid Method of Photographing Black and White Drawings, Charts, Documents, Etc.

(Contributed by R. S. B. Millett.)*

Over a period of nearly four years the use of bromide printing paper instead of the usual process film has been found highly satisfactory. The method is here described:—

1. Camera.—With film holder adaptable for cut films.

2. Kodak bromide paper, 4B1 (extra contrasty) is placed in the film holder, emulsion side facing lens.

NOTE.—In handling the paper, care should be taken to avoid leaving fingerprints, as such marks show prominently after development.

3. Exposure.—The exposure is approximately twice as long as required for Kodak process film.

4. Development of negative.—The following developer has been found to be very satisfactory:—

Gevaert developer (G254)—

Potassium hydroxide	25 g.
Sodium sulphite	100 g.
Potassium bromide	3 g.
Hydroquinone	55 g.
Water to	1,000 cc.

This developer gives maximum contrast. Time of development.—90–120 secs at 65°F.

5. After fixation and washing, the paper negative may be dried in a few minutes by immersing it in alcohol and holding over a hot plate.

6. Printing.—The procedure is exactly the same as for film. The paper negative is placed in contact with a sheet of extra contrasty bromide paper, and the light passed through the back of the negative in the usual manner.

7. Exposure.—The exposure is necessarily longer than required for process film. Once the exposure has been determined for a good negative care should then be taken to standardize the contrast of all succeeding negatives.

Advantages—

(*a*) The method is simple, and the processing may be carried out rapidly.

(*b*) The saving in cost of material is considerable. A film ($6\frac{1}{2}$ in x $4\frac{3}{4}$ in.) costs 8d., whilst bromide paper is slightly more than 1d. per sheet.

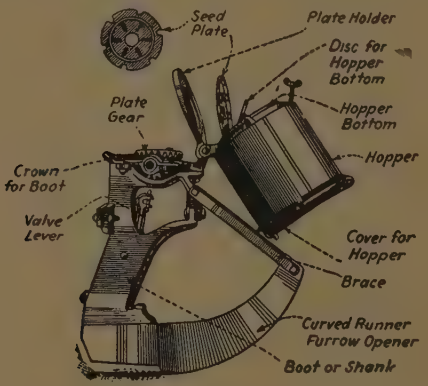
* An Officer of the Division of Plant Industry.

(*c*) The paper negatives are easier to handle than either plates or films which require more careful handling during development.

(*d*) It is possible to watch the development of the paper negative without removing it from the developer. This advantage enables the operator to obtain always negatives of the contrast required.

Attention is drawn to an article by M. Distad appearing in "The Review of Scientific Instruments," May, 1939, which appeared after the development of the method described in the foregoing.

Distad describes a method of photographing with bromide paper, but the usefulness of this method is somewhat limited.



Print from paper negative.

Review.

"Tin Solders: A Modern Study of the Properties of Tin Solders and Soldered Joints", by S. J. Nightingale, Second Edition, revised by O. F. Hudson, A.R.C.S., D.Sc.

(Published by the British Non-Ferrous Metals Research Association, Euston-street, London, N.W.1. 1942. 117 pp. Price 10s. 6d. post free (in the United States, $2.75). Obtainable from the Association or from any bookseller.)

Ten years ago the British Non-Ferrous Metals Research Association, having carried out investigations on tin solders and the requirements they have to meet in service, published a book entitled "Tin Solders: A Modern Study of the Properties of Tin Solders and Soldered Joints". The book, written by Mr. S. J. Nightingale, who conducted the investigation, enjoyed great popularity.

Since that time further work on the subject has been carried out in the B.N.F.M.R.A. laboratories and elsewhere, the Association's investigations being mainly concerned with the creep properties of

solders (including antimonial solders) and of soldered joints. Dr. O. F. Hudson has revised and considerably expanded the book to include this new matter, and a second edition is now published. Recent events, which have made us look to our tin supplies and consider ways of economising in the use of tin, will make it necessary to modify the compositions of solders used for some purposes. This can only be done efficiently if based on a sound knowledge of the properties and behaviour of existing tin solders and of the reasons determining the suitability of particular compositions for different purposes. The new edition therefore appears at an opportune moment. It is set out in two parts. The first part deals with the constitution of the tin solders; the structure of solders; the mechanical properties of the solder alloys; the strength of soldered joints; creep properties of solder alloys and soldered joints; and alloying between the solder and the joint members. The second part deals with practical considerations (such as fluxes, the wiped joint, &c.) and the choice of a solder. There are numerous illustrations and photomicrographs.

Utilization of Farm Products—U.S. Regional Research Laboratories.

The activities of the first four Regional Research Laboratories of the United States Department of Agriculture were described at the Eighth Annual Chemurgic Conference held in Chicago in March, 1942. The establishment of these laboratories was authorized by Congress in 1938, the sum of $4,000,000 a year being allotted to the project. The laboratories were to be situated one in each major farm producing area, and they were to "conduct researches into and to develop new scientific, chemical, and technical uses and new and extended markets and outlets for farm commodities and products and by-products thereof."

About three-quarters of the staff that will ultimately be employed in these laboratories is already at work on a wide variety of problems, all now concerned with national defence. Cellulose for making nitrocellulose normally comes from cotton linters; the supply of these is now insufficient and raw lint cotton and the cellulose from other farm residues are being studied as alternatve sources. Specifications and rot-proofing treatments for cotton sandbags were evolved so that they could replace jute. Methods of processing and storing dried vegetables and frozen foods are being improved.

The United States imports about half the material that is needed for tanning the leather produced in the country; one of the laboratories is making a special study of the problem of tanning materials and has found what promises to be a satisfactory source in the bark of the Western hemlock tree. The demand for casein is increasing, particularly for the manufacture of casein fibre, and the production of casein is expected to decline markedly with the increased production of dried milk and cheese. This problem is being attached in two ways; new sources of casein are being developed by using skim milk which is not available to drying or cheese plants, and other proteins are being

developed as satisfactory substitutes for casein. A protein has been extracted from soybean curd which has proved a very satisfactory substitute for casein, but this cannot so far be produced in sufficient quantity, and other substitutes being studied are feathers and related substitutes for providing plywood adhesives, and zein from maize for paper coatings. One laboratory is working on the production on a commercial scale of penicillin, which will stop the growth of streptococci and staphylococci when it is diluted as high as 1:50,000,000. Another laboratory has completed a pilot plant which is producing 500 gallons of motor spirit a day from agricultural products. Work on the production of rubber extenders and synethetic rubber is also yielding useful results.

These are only a few of the problems now being studied in the four Regional Research Laboratories, but they indicate some of the ways in which the laboratories have been able to assist in national defence during the first twelve months of their existence.

Recent Publications of the Council.

Since the last issue of the *Journal,* the following publications of the Council have been issued:—

Bulletin No. 148.—"Studies in Fertility in Sheep. II. Seminal Changes Affecting Fertility in Rams," by R. M. C. Gunn, D.V.Sc., B.Sc.Agr., M.R.C.V.S., R. N. Sanders, B.V.Sc., and W. Granger, B.V.Sc.

This Bulletin describes work carried out by Dr. Gunn and his colleagues in the University of Sydney.

One of the problems of the Australian sheep industry is the relatively poor lambing which may occur sometimes in flocks that usually produce well, or which may occur more or less regularly in flocks in some of the less favoured areas in Australia. Initial observations having been made on the seasonal variations in the semen characters of rams in Western New South Wales, experiments were conducted to determine the effects of artificial hot dry atmospheres on ovine spermatogenesis. These were found to cause seminal degeneration varying in degree with the height of the temperature and the duration of exposure to it. Seminal degeneration has also been found to be associated with fly-strike, other conditions causing fever, and certain clinical conditions unassociated with high fever, such as contagious footrot.

Dipping merino rams in standard arsenical dips at recommended strengths has been shown to cause seminal degeneration owing to the absorption of arsenic through the general body surface. Such absorption and degeneration is most marked in long-fleeced rams dipped in hot humid weather, but may occur in other circumstances.

Bulletin No. 149.—"Production of Dried Grapes in Murray Valley Irrigation Settlements. 2. Irrigation, Drainage, and Reclamation," by A. V. Lyon, M.Agr.Sc., and A. L. Tisdall, M.Agr.Sc.

This Bulletin is the second of a series dealing with the production of dried grapes in Murray Valley Irrigation settlements. The previous Bulletin discussed viticultural practices; the present one deals with irrigation, drainage, and reclamation of soils used for vine growing.

It is estimated that nearly a million acres are now irrigated with waters from the Murray Valley, and some areas have been irrigated for over 50 years. It was for some time feared that soil deterioration was inevitable with irrigation, but investigations have shown that practically all the irrigated lands of the Murray can be kept in production if adequate measures are taken to prevent soil wastage. No more irrigation water than is absolutely necessary should be applied, and suitable means of drainage should be provided. Where simple waterlogging rather than salt damage is the main problem, cover crops such as tick beans are useful in absorbing excess water, and they also improve the soil.

For light textured soils subect to waterlogging, subsurface drainage has provided the only real solution for soil wastage, and, where drainage systems are installed before the soils are too greatly damaged, reclamation by underground tile drains is often quick and spectacular. For soils of heavy texture, such as predominate in the Woorinen, Kerang, and Murrumbidgee areas, surface drainage for removal of excess irrigation water and storm waters has been found necessary. On the great majority of soils, drainage has not only improved the land, no matter how serious the deterioration had been, but has proved to be economically sound for crops of high productive value. For fodder and pasture lands, however, the cost of tile drainage is usually considered excessive.

Pamphlet No. 113.—"Drainage Investigations in the Horticultural Soils of the Murray Valley," by A. L. Tisdall, M.Agr.Sc.

This Pamphlet discusses the adaption of drainage methods to suit each particular soil and locality, and the means of evaluating drainage efficiency. Plant-health surveys, effluent measurements, and water-table examinations have been found useful in this connection, and soil moisture contents have also been used for confirmatory evidence. Plant surveys have the disadvantage that several years are required before conclusive results are obtained, and effluent measurement is only possible where irrigation water can be controlled and measured. Water-table measurements can be made simply and with sufficient accuracy by means of test wells, the design and lay-out of which are described.

European experience is that drain depth depends little on soil conditions, but in the soils which predominate in the Murray Valley, the most satisfactory depth depends almost entirely on soil profile, and it was necessary to determine afresh the correct depth and spacing of drains for each major soil type.

Pamphlet No. 114.—"Plant Introduction. 1. A Review with Notes on Outstanding Species," by A. McTaggart, Ph.D. "2. Preliminary Selection and Evaluation of Pasture Species at Lawes (Queensland)," by T. B. Paltridge, B.Sc.

This Pamphlet reviews briefly some of the most promising pasture plants introduced into Australia by the Council during the last decade. The three main stations for testing introduced plants are located at

Canberra, A.C.T., Lawes, South Queensland, and Rockhampton, Central Queensland, but there are other subsidiary testing areas in New South Wales and Queensland. The chief characteristics being sought in pasture plants tested at Lawes are given, and the methods used in their selection and evaluation are described.

One of the most promising plants introduced so far by the Division of Plant Industry is the legume *Stylosanthes guianensis*, which was introduced from Brazil in 1933. This plant, because of its special adaptation to the northern half of Queensland and to northern Australia generally, its ability to provide rich and palatable pasture practically the year round, its natural regenerating capacity, its suitability to light soils, its drought-resisting quality, its capacity to combine with grasses, its apparent ease of establishment in existing swards, and its capability of assuming the role of lucerne under tropical conditions, bids fair to ultimately supply a long-felt want, namely, that of providing a legume for northern Australian pastures of low protein content by reason of their natural deficiency in legumes.

At Lawes, with its summer rainfall, normal conditions favour fast-growing annual pasture plants, with a high water requirement, but these are subject to serious damage from short-duration droughts, which are of frequent occurrence. Perennial species are less affected by droughts, but their growth is generally limited by low temperatures during the six winter months. The most promising line of pasture improvement in this region seems to be the introduction of summer-growing perennial grasses, which should have capacity for continued production during the spring drought, should not rapidly go to seed or become unpalatable during the growing season, and should retain their palatability and nutritional value as standing fodder during the winter months when their growth rate is at a minimum.

Pamphlet No. 115.—"Studies on the Shrink-proofing of Wool. 1. The Industrial Development of the Freney-Lipson Process at Hole-proof Limited, Melbourne. 2. Further Studies on the Prevention of Shrinkage in Woollen Goods," by M. Lipson, B.Sc., A.A.C.I., and Carmel J. Clyne, B.Sc. "3. Experimental work on the Treatment of Wool by the Woolindras Process," by D. R. Zeidler, M.Sc.

This Pamphlet gives further details of the development and commercial application of the Freney-Lipson process for shrink-proofing wool, which was discovered by officers of the Council. It also described experimental work carried out in Australia on the Woolindras shrink-proofing process, developed by the Wool Industries Research Association on Torridon, England.

By the Freney-Lipson process, wool is treated with alcoholic solutions of certain alkalies. The process may be applied to wool in the form of tops or at any stage up to the production of the finished garment, and renders it satisfactorily unshrinkable. Recent work has emphasized the importance of temperature control in the successful application of the process; temperatures between 20° and 25°C. are most satisfactory. The water content of the alkali must be within the range 1 to 5 per cent.

The Woolindras process consists of treating wool or woollen goods with dry chlorine under certain conditions. The tests described were carried out with a plant obtained from England by the Council to

demonstrate the process to Australian wool manufacturers. The most critical factor in the operation of this process is the moisture content of the wool to be treated, which must be very carefully regulated. Cost of treatment, exclusive of overhead and maintenance charges, is estimated at slightly under 2d. per lb.

Industrial Chemistry Circular No. 1.—"Some Technical Aspects of Foundry Cores," by H. A. Stephens, B.Sc.

This Circular discusses some technical aspects of foundry cores, giving details of types of cores and binders, methods of baking cores, and means of testing core sands.

Organically bonded cores may be divided into six simple classes. They have different effects on the core sand and are used for different purposes. Preliminary tests have been made on Australian grass-tree or yacca resin; it has proved very satisfactory for binding cores used where high contraction is encountered.

The effect of baking temperature on the strength of cores is emphasized. Samples of a core mixture were baked at 200°C., which was correct for the type, and at 250°C.; there was a fall of 95 per cent. in the strength of the samples baked at the higher temperature. To prevent heat wastage in baking ovens, insulation is necessary, and it is pointed out, for example, that 4 inches of rock wool has about ten times the insulating power of a 13-in. course of fire brick.

Testing methods described for foundry cores are those adopted by the American Foundrymen's Association. The principles which apply to the selection of core sands are similar to those applying to moulding sands. In general, the smaller the size of the work and the lower the pouring temperature of the metal, the finer the sand which can be used. The core sands required for various types of work are outlined.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 150.—"The Soils of the Parishes of Longford, Cressy, and Lawrence, County Westmorland, Tasmania. 1. A Soil Survey of the Area. 2. Pot Experiments with Subterranean Clover on the Cressy Shaley Clay-loam," by C. G. Stephens, M.Sc., A.A.C.I., J. G. Baldwin, B.Agr.Sc., B.Sc., and J. S. Hosking, M.Sc., A.I.C., A.A.C.I.

Bulletin No. 151.—"The Control of St. John's Wort (*Hypericum perforatum* L. var. *angustifolium* D.C.) by Competing Pasture Plants," by R. M. Moore, B.Sc.Agr., and A. B. Cashmore, M.Sc.

Bulletin No. 152.—"Soil Survey of Part of County Moira, Victoria, including the Parishes of Boosey, Cobram, Katamatite, Naringaninga-look, Katunga, Yarroweyah, and Strathmerton," by B. E. Butler, B.Sc.Agr., J. G. Baldwin, B.Agr.Sc., B.Sc., F. Penman, M.Sc., and R. G. Downes, M.Agr.Sc.

Bulletin No. 153.—"Pelagic Tunicates in the Plankton of South-eastern Australian Waters, and their Place in Oceanographic Studies," by H. Thompson, M.A., D.Sc., with a Statistical Analysis of Data on Total Plankton, by G. L. Kesteven, B.Sc.

Bulletin No. 154.—"The Handling and Storage of Australian Oranges, Mandarins, and Grapefruit." Report of Investigations carried out under the direction of the Citrus Preservation Technical Committee from 1935 to 1941, and compiled by F. E. Huelin, B.Sc., Ph.D.

Bulletin No. 155.—"The Lubricating Effect of Thin Metallic Films and the Theory of the Action of Bearing Metals," by F. P. Bowden, Sc.D. (Cantab.), and D. Tabor, Ph.D. (Cantab.), A.R.C.S.

Bulletin No. 156.—"Standardized Plant Names. A List of Standard Common Names for the more Important Australian Grasses, other Pasture Plants, and Weeds," prepared by the Division of Plant Industry.

Bulletin No. 157.—"Studies in the Biology of Australian Mullet. 1.—Account of the Fishery and Preliminary Statement of the Biology of *Mugil dobula* Gunther," by G. L. Kesteven, B.Sc.

H. E. Daw, Government Printer, Melbourne.